Taylor (W. B.)

AN HISTORICAL SKETCH

OF

HENRY'S CONTRIBUTION

TO THE

ELECTRO-MAGNETIC TELEGRAPH:

WITH

AN ACCOUNT OF THE ORIGIN AND DEVELOPMENT OF PROF. MORSE'S INVENTION.

BY WILLIAM B. TAYLOR.

[FROM THE SMITHSONIAN REPORT FOR 1878.]

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HENRY AND THE TELEGRAPH.

By William B. Taylor.

> "Yet though thy purer spirit did not need
> The vulgar guerdon of a brief renown,
> Some little meed at least—some little meed
> Our age may yield to thy more lasting crown."

In the impulsive tide of popular applause which follows the consummation of great enterprises, or the material advancement from new conquests of natural law, the labors and merits of those who patiently laid the deep and broad foundations of these successes, or who with rarest diligence, sagacity, and skill, made such successes practicable, are usually whelmed; and—save by the scientific student, are mostly forgotten and ignored. And this result is the more assured by reason of the entire self-unconsciousness and devotion with which the higher work of original research is conducted, with no disturbing thought on the part of the investigator, of reaping immediate advantage or reward from the bestowal of the new discovery.

> "For praise is his who builds for his own age;
> But he who builds for time, must look to time for wage."*

That the award of time respecting Henry's true relation to the telegraph will be discriminating and just, may be confidently anticipated, since the materials and data for an accurate judgment are already matter of enduring record.† In attempting here to briefly review this record, justice will best be done to Henry's fame by rendering full justice to Henry's predecessors.

The Growth of the Electric Telegraph.—"The electric telegraph had properly speaking, *no inventor.* It grew up little by little, each inventor adding his little to advance it toward perfection."‡ These words of soberness and truth are little apprehended by the multitude; who blind alike to the beginnings and to the growths of great ideas, contemn the

* Prof. Grant Allen.

†In the spirit of Kepler (though with less of self-assertion), Henry, with a modest estimate of his own contributions to science, while evincing a remarkable indifference to popularity, yet with the quiet confidence of a clear and impartial judgment, declared "I was content that my published researches should remain as material for the history of science, and be pronounced upon according to their true value by the scientific world."—(*Smithsonian Report* for 1857, p. 87.)

‡ *The Electric Telegraph.* By Robert Sabine. 8vo. London, 1867, part i, chap. iv, sect. 39, p. 40.

discoverer while they deify the artisan. When Galvani about a century ago (1786) first opened slightly the door to one of nature's marvels, that large community ever distinguished by the vigor of its common sense and the practical solidity of its judgment, asked with ready instinct the wise and ancient question, "What is the *use* of it?" And a majority of those who recognized the experimenter's appearance on the streets of Bologna, pointed him out as the "frog philosopher." Their descendants and representatives at the present day have neither lost—nor gained in wit.*

It is proposed to notice the development of the electric telegraph somewhat at length, in order to exhibit more clearly the precise nature and value of Henry's contribution to its practical establishment and success. This survey naturally divides itself into a chronological review of the successive though overlapping applications—of frictional or mechanical electricity (first suggested by Franklin? or by Lesage? about the middle of the last century); † of galvanism or chemical electricity (first suggested by Sœmmering in 1808); and of galvano-magnetism (first suggested by Ampère in 1820). ‡

Among the numerous flights of imagination by which genius has frequently anticipated the achievements of her more deliberate and cautious sister—earth-walking reason, none is perhaps more striking than the romantic conception by Famianus Strada, of Rome, in the early part of the seventeenth century, of an intercourse maintained between separated friends by means of two sympathetic magnetic compasses, whereby the indications on the dial given by one, were instantly made visible to the other. §

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* On the value of abstract science, see "Supplement," NOTE A.

† Mr. Stephen Gray, in a letter to Dr. Cromwell Mortimer, secretary of the Royal Society of London, dated February 8, 1731, recited among numerous electrical experiments, the passage of sparks and the excitation of an electroscope, effected through 293 feet of wire suspended by silk, in 1729; through 666 feet on July 3 of that year; a week or two later, through 765 feet; and in August, 1730, through 886 feet of wire. (*Phil. Trans. R. S.* 1731, vol. xxxvii, No. 417, pp. 29, 31, and 44.) These experiments were made however for the purpose of determining conductive capacity, without any view of employing the indications for signals.

A letter was published in the *Scots' Magazine*, dated Renfrew, February 1, 1753, and signed "C. M.," which, under the title "An expeditious method of conveying intelligence," proposed the suspension between two distant points of a number of insulated wires (equal to the number of letters in the alphabet), through which electrical discharges should separately exhibit themselves by the diverging balls of an electroscope, or the striking of a bell by the attraction of a charged ball. The author of the communication was supposed by Sir David Brewster to be a Charles Marshall, of Paisley. (*The Engineer*, London, Dec. 24, 1858, vol. vi., p. 484.) It is probable that G. L. Lesage, of Geneva, entertained the project of an electric telegraph as early as the middle of the last century. It was therefore rather the impulse of an age, than the inspiration of an individual.

‡ The application of magneto-electricity, presenting no essential differences from the use of galvano-electricity, (for which it is sometimes substituted,) requires no special notice. Still less noteworthy is the project of thermo-electricity as the motor.

§ *Prolusiones Academicæ:* by F. Strada, quarto, Rome, 1617, lib. ii, prolusio 6. A century later, (but still a third of a century before man dreamed of electric telegraphs,) Joseph Addison presented the following version of this fairy tale: "Strada, in one of his Prolusions, gives an account of a chimerical correspondence between two friends by the help of a certain loadstone which had such a virtue in it that if it

"Two faithful needles—from the informing touch
Of the same parent stone, together drew
Its mystic virtue;——
And though disjoined by kingdoms,—though the main
Rolled its broad surge betwixt,—and different stars
Beheld their wakeful motions,—yet preserved
Their former friendship and remembered still
The alliance of their birth." *

It needed but the later discovery of the galvanic wire for connecting the two needles, to realize completely this vision of an "oriental" fancy, and to render it the sober experience of our present every-day life.

I.—TELEGRAPHS BY ELECTRICITY.

If the earlier attempts commencing in the last century to apply so-called "static" electricity to the purpose of telegraphy may to some appear to possess only an antiquarian interest, it will be seen that they form the necessary, and by no means insignificant, childhood of our modern systems. Neglecting generally mere speculations, as well as initial conceptions of executed schemes, the following comprise the more important experimental devices, in the order of their approximate realization.

1774. The first electric telegraph of which there is record, is that established at Geneva by Georges-Louis Lesage. The line consisted of 24 insulated wires for the alphabet, each terminating in a pith-ball electroscope duly lettered, for indicating by its excitement the succession forming the words and sentences given by the operator, who employed at the transmitting station a manual conductor from an electrical machine. †

1787. M. Lomond, at Paris, had a single brass wire extended from one closed apartment to another at some distance from it, in connection with a pith-ball electroscope at each end, by which arrangement he was able to communicate sentences in either direction. Arthur Young, the diligent writer on natural and industrial resources, has thus described the apparatus in his journal: October 16, 1787,—" In the evening, to Mons.

touched two several needles, when one of the needles so touched began to move, the other though at never so great a distance, moved at the same time and in the same manner. He tells us that the two friends being each of them possessed of one of these needles, made a kind of dial-plate, inscribing it with the four-and-twenty letters, in the same manner as the hours of the day are marked upon the ordinary dial-plate. They then fixed one of the needles on each of these plates in such a manner that it could move round without impediment, so as to touch any of the four-and-twenty letters. . . . By this means they talked together across a whole continent, and conveyed their thoughts to one another in an instant over cities or mountains, seas or deserts." (*The Spectator*, No. 241, Dec. 6, 1711.) A similar idea (probably borrowed from Strada) is found in Daniel Schwenter's *Mathematisch-philosophische Erquickungsstunden;* published at Nuremberg in 1636, pp. 346, 347.

*Akenside, *Pleasures of Imagination* (1744), book iii.

† Lesage, in a letter addressed to Prof. Pierre Prévost, of Geneva, dated Berlin, June 22, 1782, describing to his friend the details of his telegraph, states that the method of corresponding by means of electricity had been contemplated by him for thirty or thirty-five years. (*Traité de Télégraphie Électrique:* par l'Abbé Moigno, 2d edit. 8vo. Paris, 1852, part ii, chap. 1, p. 59.)

Lomond, a very ingenious and inventive mechanic, who has made an improvement of the jenny for spinning cotton. In electricity he has made a remarkable discovery. You write two or three words on a paper; he takes it with him into a room, and turns a machine inclosed in a cylindrical case, at the top of which is an electrometer,—a small fine pith ball; a wire connects with a similar cylinder and electrometer in a distant apartment; and his wife by remarking the corresponding motions of the ball, writes down the words they indicate. From which it appears that he has formed an alphabet of motions. As the length of the wire makes no difference in the effect, a correspondence might be carried on at any distance." *

1794. M. Reiser, at Geneva, arranged a line of 36 insulated wires, each separately connected at the receiving-station with a small grating of narrow tin-foil strips pasted on glass, from which a letter or figure had been cut, so as to represent the character by the passage of the electric spark over the series of narrow spaces. On a square plate were fastened 36 of these independent gratings, representing the 26 letters and 10 numerals. "The instant the discharge is made through the wire, the spark is seen simultaneously at each of the interruptions or breaks of the tin-foil constituting the letter, and the whole letter is rendered visible at once." The sparks were transmitted through the selected wire and its corresponding symbol from a small electrical machine kept in operation at the sending station.†

1795. Tiberius Cavallo, in England, experimented with electric signals of various kinds (explosive and otherwise) through a long and tolerably fine copper wire (about the fortieth of an inch in diameter) insulated by successive coatings of pitch, linen strips, woolen cloth, and oil-painting. He found a Leyden jar of about one square foot, sufficient for the required electric spark, if the length of the wire did not exceed 200 feet. He remarks: "By sending a number of sparks at different intervals of time according to a settled plan, any sort of intelligence might be conveyed instantaneously from the place in which the phial is situated. With respect to the greatest distance to which such communication might be extended, I can only say that I never tried the experiment with a wire of communication longer than about 250 feet; but from the results of those experiments, and from the analogy of other facts, I am led to believe that the above-mentioned sort of communication might be extended to two or three miles, and probably to a much greater distance."‡

* *Travels during the years* 1787, 1788, *and* 1789, *in the Kingdom of France.* By Arthur Young. 2 vols. 8vo. Dublin, 1793, vol. i, p. 135. Of the work as republished in Pinkerton's *Collection of Voyages and Travels*, 4to. London, 1809, vol. iv, p. 139.

† Voigt's *Magazin*, etc. 1794, vol. ix, part 1, p. 183; also Moigno's *Télégraphie Électrique*, part ii, chap. 1, p. 61.

‡ *A Complete Treatise on Electricity*, in 3 vols. 8vo. London, 1795; vol. iii, note No. viii, pp. 295, 296. The first *two* volumes of this work had passed through three earlier editions.

1798. D. F. Salva, in Spain, appears to have successfully worked an electric telegraph through the unprecedented distance of twenty-six miles. "The *Madrid Gazette* of November 25, 1796, states that the Prince de la Paix, having heard that M. D. F. Salva had read to the Academy of Sciences a memoir upon the application of electricity to telegraphing, and presented at the same time an electric telegraph of his own invention, desired to examine it; when being delighted with the promptness and facility with which it worked, he presented it before the king and court, operating it himself. Some useful trials were made and published in *Voigt's Magazine*. Two years after, the Infanta Don Antonio constructed a telegraph of great extent on a large scale, by which the young prince was informed at night of news in which he was much interested. He also invited and entertained Salva at court. According to Humboldt, a telegraph of this description was established in 1798, from Madrid to Aranjuez, a distance of 26 miles."*

1816. Francis Ronalds constructed at Hammersmith, England, an experimental telegraph line of a single wire, operated by an electrical machine, or small Leyden jar. "He proved the practicability of such a scheme by insulating eight miles of wire on his lawn at Hammersmith. In this case the wire was insulated in the air by silk strings. . . . Mr. Ronalds fixed a circular brass plate upon the seconds arbor of a clock which beat dead seconds. This plate was divided into twenty equal parts, each division being worked by a figure, a letter, and a preparatory sign. The figures were divided into two series of the units, and the letters were arranged alphabetically, omitting J, Q, V, W, X, and Z. In front of this was fixed another brass plate (which could be occasionally turned round by hand), and which had an aperture that would just exhibit one of the figures, letters, and preparatory signs. In front of this plate was suspended a pith-ball electrometer from a wire which was insulated and which communicated on one side with a glass cylinder machine. At the farther end of the wire was an apparatus exactly the same as the one now described, and the clocks were adjusted to as perfect synchronism as possible. Hence it is manifest that when the wire was charged by the machine at either end, the electrometers at both ends diverged, and when it was discharged they collapsed at the same instant; consequently if it was discharged at the moment when a given letter, figure, and sign on the plate appeared through the aperture, the same letter, figure, and sign would appear also at the

* *The Electro-Magnetic Telegraph*, by Laurence Turnbull, 8vo. 2d ed. Philada. 1853, pp. 21, 22. Voigt's *Magazin*, etc. vol. xi, part 4. The same telegraphic feat is attributed to Bétancourt. "Gauss makes mention of a communication from Humboldt, according to which Bétancourt, in 1798, established a communication between Madrid and Aranjuez, a distance of 26 miles, by means of a wire through which a Leyden jar used to be discharged, which was intended to be used as a telegraphic signal." (Sturgeon's *Annals of Electricity*, etc. March, 1839, vol. iii, p. 446.) This is probably a misapprehension: as Augustine Bétancourt (more correctly Bethencourt), a Spanish engineer, in 1798, devised and exhibited to the National Institute an improvement in the mechanical semaphore. (Brewster's *Edinburgh Encyclopædia*, 1830, art. "Telegraph,' vol. xviii, p. 535.)

other clock; so that by means of such discharges at one station, and by marking down the letters, figures, and signs seen at the other, any required words could be spelt."*

"He also made the trial with 525 feet of buried wire. With this view he dug a trench four feet deep, in which he laid a trough of wood two inches square, well lined both within and without with pitch; and within this trough were placed thick glass tubes through which the wire ran. The junction of the glass tubes was surrounded with short and wider tubes of glass, the ends of which were sealed up with soft wax." This form of conductor was not found to operate very satisfactorily, and the inventor on theoretical grounds did not think such an arrangement adapted to the instantaneous electrical transmission required by his system.

Mr. Ronalds, in 1823, published a full account of his telegraph.† In 1871, very nearly half a century later, as Sir Francis Ronalds, he published a new edition of this interesting work; and a review of it in "Nature" gives this presentation of the scheme: "Sir Francis, before 1823, sent intelligible messages through more than eight miles of wire insulated and suspended in the air. His elementary signal was the divergence of the pith-balls of a Canton's electrometer, produced by the communication of a statical charge to the wire. He used synchronous rotation of lettered dials at each end of the line, and charged the wire at the sending end whenever the letter to be indicated passed an opening provided in a cover; the electrometer at the far end then diverged, and thus informed the receiver of the message which letter was designated by the sender. The dials never stopped, and any slight want of synchronism was corrected by moving the cover."‡

This very ingenious device of synchronous rotation at the opposite stations presents the earliest example of a dial telegraph, or of a letter indicator employing but a single wire. About forty years later, or in 1855, this system was successfully applied by Mr. David E. Hughes, of Kentucky, to a letter-printing telegraph of remarkable rapidity and accuracy.§

1828. "Harrison Gray Dyar, an American, constructed a telegraph in 1827–'28, at the race-course on Long Island, and supported his wires by glass insulators fixed on trees and poles. By means of common electricity acting upon litmus paper he produced a red mark. The difference of time between the sparks indicated different letters arranged in an ar-

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* *Encyclopædia Britannica*, 7th ed. 1842, vol. viii, p. 662.—8th ed. 1854, vol. viii, p. 627.

† *Descriptions of an Electrical Telegraph; and some other Electrical Apparatus.* By Francis Ronalds. 8vo. London, 1823.

‡ *Nature.* London, Nov. 23, 1871, vol. v, p. 59.

§ A second type of dial telegraph was invented by Prof. Charles Wheatstone in 1839, in which the dial (or index) was rotated step by step by means of successive impulses of the current on an electro-magnet, which operated a toothed escapement on the axis of the dial or index;—the indicated letter or figure being stopped as long as desired. In this case, the character was determined solely by the number of electric impulses transmitted. This system was in 1846, made the basis of a highly original letter-printing telegraph, by Mr. Royal E. House, of Vermont; preceding that of Mr. Hughes, as will be observed, nearly ten years.

bitrary alphabet, and the paper was moved by the hand." * Mr. Dyar is described by Dr. Luther V. Bell as "a man of the highest inventive skill and scientific attainments." His experimental line (of a single wire) was several miles long; and the chemical record of the signals transmitted through it, was by the testimony of those who witnessed its operations, eminently distinct and satisfactory. The following is the account of his enterprise, given by the inventor himself in 1849, some twenty years afterward:

"I invented a plan of a telegraph which should be independent of day or night or weather, which should extend from town to town or city to city, without any intermediary agency, by means of an insulated wire in the air, suspended on poles, and through which wire I intended to send strokes of electricity in such a manner as that the diverse distances of time separating the divers sparks should represent the different letters of the alphabet and stops between the words, etc. This absolute or this relative difference of time between the several sparks I intended to take off from an electric machine by a little mechanical contrivance regulated by a pendulum, and the sparks were intended to be recorded upon a moving or a revolving sheet of moistened litmus paper, which by the formation of nitric acid by the spark in the air in its passsage through the paper, would leave a red spot for each spark on this blue test-paper. . . . To carry out my invention I associated myself with a Mr. Brown, of Providence, who gave me certain sums of money to become associated with me in the invention. We employed a Mr Connel, of New York. to aid in getting the capital wanted to carry the wires to Philadelphia. This we considered as accomplished: but before beginning upon the long wire, it was decided that we should try some miles of it on Long Island. Accordingly I obtained some fine card wire, intending to run it several times around the race-course on the Island. We put up this wire (that is, Mr. Brown and myself) at different lengths, in curves and straight lines, by suspending it from stake to stake and tree to tree until we concluded that our experiments justified our undertaking to carry it from New York to Philadelphia. At this moment our agent brought a suit or summons against me for 20,000 dollars for agencies and services, which I found was done to extort a concession of a share of the whole project." Failing in this prosecution, the unprincipled agent obtained a writ against the two partners on a charge of conspiracy to carry on secret communication between the cities! and he thus effectually put an end to the enterprise, without the formality of a judicial trial on this novel accusation.†

These practical illustrations of early electric telegraphy, including successful workings of both the dial and the chemical forms of the telegraph without the use of galvanism, serve to show that the agency is by

* Turnbull's *Electro-Magnetic Telegraph*, 8vo. Philadelphia, 1st ed. 1852, p. 6; 2d ed. 1853, p. 22.

† Prescott's *Hist. Electr. Telegraph*, 1860, chap. xxi, pp. 427, 428.

no means the trivial and inefficient one so often represented by modern writers. On the contrary, but for the practical difficulty of perfect and constant insulation, owing to the intense self-repulsion of mechanical electricity and the reaction and retardation from induction currents in long lines of coated wire, this method would really constitute an economical and satisfactory medium of distant communication.

Steinheil in reference to this subject remarks: "All these experiments put it beyond a doubt that frictional electricity may be employed for giving signals at any distances, and that when these signals are properly contrived they offer convenient means of telegraphic intercourse. Frictional electricity has besides as Gauss has already observed, the great advantage of not losing any of its force by increasing the length of the conducting wire, inasmuch as the whole of the electricity of one coating of the jar must traverse the entire length of the wire (be it what it may) to neutralize that of the other coating."*

II.—TELEGRAPHS BY GALVANISM.

The introduction of the galvanic battery by Volta at the commencement of the present century† led many to experiment with its peculiar current as a means of telegraphing. The only practicable forms of simple galvanic telegraphs, are those whose indications are given by chemical decompositions, and which thus form the class commonly known as the "electro-chemical"; and as these chemical indications usually leave permanent markings, the class is also one of *recording* telegraphs.

1808. Dr. Samuel Thomas von Sœmmering, of Munich, appears to have been the first to apply Volta's invention to this purpose. "As long ago as in 1807, Sœmmering erected in the apartments of the Academy of Sciences at Munich a galvanic telegraph, of which he has published a detailed description in the Philosophical Transactions of Bavaria. [*Münchner Denkschriften der Königlichen Akademie der Wissenschaften für* 1809, 1810. Math. phys. Classe, p. 401.] He employed the energy of a powerful voltaic pile to bring about the decomposition of water by means of thirty-five gold pins immersed in an oblong glass trough."‡ Each of these gilt electrodes was in connection with one of the thirty-five wires forming the line, and was covered with an inverted test-tube filled with water, resting on a submerged shelf in the oblong trough, as a gas-receiver. These small receivers with their inclosed gilt pins or electrodes arranged in a row, represented 25 letters and 10 numerals. Such being the disposition at the receiving end, the thirty-five line wires at the transmitting end were each secured to a separate perforated brass plate. On connecting the

* Sturgeon's *Annals of Electricity*, etc. March 1839, vol. iii, p. 446.

† Volta's description of his battery is given in a "Letter to Sir Joseph Banks," president of the Royal Society of London. (*Phil. Trans. R. S.* read June 26, 1800, vol. xc, pp. 403–431.)

‡ Sturgeon's *Annals of Electricity*, etc. Mar. 1839, vol. iii, p. 447.

respective poles of the battery with any two of the line wires by means of two attached metallic pins held in the hands and inserted in the holes of their terminal plates, the current was established, and bubbles of hydrogen and oxygen were at once evolved in the corresponding lettered tubes. A system of syllabic communication and reading was provided, in which the hydrogen element should be first noted.*

Very shortly after his first successful working of this telegraph, Sœmmering interposed in the galvanic circuit two thousand feet of insulated wire, wound around a glass cylinder, without impairing his decompositions. He found no appreciable retardation in the action of the electrodes. "The evolution of the gas through this considerable length of wire appeared to begin as quickly as if the effect had only to traverse two feet." †

In an "Historical account of the introduction of the galvanic and electro-magnetic telegraph" presented to the Imperial Academy of Sciences at St. Petersburg, by Dr. Hamel, of that city, a very full and interesting narrative is given of Sœmmering's experiments, compiled from original documents; ‡ from which the following extracts are made:

"On the 22d of July, 1809, his apparatus was already so far advanced that it was fit to work. He however went on making still further improvements, and it was only on the 6th of August that he considered the telegraph quite completed. He was much pleased with its performance, being able to work through 724 feet of wire. . . . Two days later, he could already telegraph through 1,000 feet, and on the 18th of August through as much as 2,000 feet of wire. On the 29th of August he exhibited the telegraph in action before a meeting of the Academy of Sciences in Munich." A year later he first effected a satisfactory arrangement of premonitory alarm or attention call. "On the 23d of August, 1810, Sœmmering succeeded in inventing a contrivance for sounding an alarm, which answered perfectly well." (p. 596.)

"In September, 1811, Sœmmering simplified his telegraph considerably; he reduced the number of wires in his conducting cord from 35 to 27. . . . On the 1st of February, 1812, Prince Karl Theodor, the second son of King Maximilian I, honored Sœmmering with a visit to see the telegraph. On the 4th of February, 1812, Sœmmering announced that he was able to telegraph through 4,000 feet of wire, and on the 15th of March he telegraphed even through 10,000 feet." (p. 597.) This was nearly two miles of wire, but wound on reels.

This complex and inconvenient arrangement of signaling by the decomposition of water, would hardly seem to offer a practical method of telegraphy. Yet the system was earnestly prosecuted by its inventor for

* Schweigger's *Journal für Chemie und Physik*, 1811, vol. ii, part 2, pp. 217–213: (from the *Memoirs* of the "*Königliche Akademie der Wissenschaften*," at Munich, 1810.) Also, *Polytechnisches Central-Blatt*, June, 1838, Jahrgang iv, b. i, pp. 482–484.

† *Münchner Denkschriften der Königlichen Akademie der Wissenschaften* für 1812. In this experiment, the self-induction of the conducting coil probably increased somewhat the effect.

‡ *Journal of the Society of Arts*, London, July 22, and 29, 1859, vol. vii, No. 348, pp. 595–599, and No. 349, pp. 605–610.

many years, and attracted considerable attention; and had no simpler device been discovered it might possibly have won its way into use. It is remarkable that some seven or eight years later a Philadelphian independently proposed the same scheme.

1816. Dr. John Redman Coxe, of Philadelphia, professor of chemistry in the University of Pennsylvania, suggested the employment of wires for communicating intelligence by a galvanic current, arranged either to decompose water in tubes, (Sœmmering's plan, of which he seems to have been unaware,) or to decompose metallic salts.* As an untried suggestion, this has been noticed only because the latter project was afterward successfully developed and executed by others.

1828. Victor Triboaillet de Saint Amand proposed to establish a galvanic telegraph line of a single wire from Paris to Brussels, the conducting wire to be varnished with shellac, wound with silk, coated with resin, inclosed in sections of glass tube carefully luted with a resin, the whole substantially wrapped and water-proofed, and finally to be buried some feet deep in the earth. The signaling device is somewhat obscure, as while a strong battery is the source of the current, the receiving instrument is an electrometer.† This project, also belonging to the purely speculative class, scarcely deserves a notice.

1843. Mr. Robert Smith, of Blackford, Scotland, devised an experimental galvano-chemical telegraph carrying out practically the suggestion offered by Dr. Coxe in 1816. A set of iron type at the receiving station, each connected by separate wires with a corresponding circuit-key at the transmitting station, was so arranged with reference to a clock-moved band of paper wet with a solution of ferro-cyanide of potassium, that when the current was passed through any special circuit, it impressed a blue letter on the band. "A paper containing an account of this telegraph was read before the Royal Scottish Society of Arts on the 27th of March, 1843; reported on by a committee, and approved the 12th of June following. Since that time many trials have been made, and various improvements in its construction have also been introduced by the inventor." ‡

Two or three years later Mr. Smith reduced his line to a single circuit of two wires; and the registering device at the receiving station consisted of a fillet or ribbon of plain calico wound on a roller placed in a trough filled with a solution of ferro-cyanide of potassium containing a few drops of nitric acid, and unrolled by the motion of clock-work over a leaden cylinder with which one of the iron wires of the line was in connection, while the end of the other iron wire rested on the wetted

*Thomson's *Annals of Philosophy*, Feb. 1816, vol. vii, p. 162.

†*Report of Academy of Industry*, Paris. Quoted from A. Vail's *Electro-Magnetic Telegraph*, 1845, p. 135. Also Turnbull's *Electro-Magnetic Telegraph*, 2d ed. 1853, p. 56.

‡*Practical Mechanic and Engineer's Magazine*, Glasgow, Nov. 1845, vol. i, 2d series, p. 36.

calico immediately over the cylinder. On every completion of the circuit at the transmitting station, a blue mark was thus imprinted on the moving cloth by the electrical decomposition, and the succession of marks of differing lengths and intervals formed the system of signals. This telegraph was found to work satisfactorily through eighteen hundred yards of wire fence.*

1846. Mr. Alexander Bain, of Edinburgh, obtained an English patent for a galvano-chemical telegraph, which while exhibiting considerable ingenuity in its mechanical devices, imitated very closely in its chemical record the previous system of Smith. "The chemical solution preferred for the preparation of the paper consists of sulphuric acid and a solution of prussiate of potassa."†

1849. Prof. Samuel F. B. Morse, of New York, obtained an American patent for a galvano-chemical telegraph, also very similar to that of Smith, employing like him a single circuit, and specifying, among several metallic salts which might be used, solutions of iodide of potassium, of iodide of tin, and of acetate of lead, with nitrate of potassa. The inventor added: "I wish it to be understood that I do not confine myself to the use of the substances I have mentioned, but mean to comprehend the use of any known substance already proved to be easily decomposed by the electric current."‡

III.—TELEGRAPHS BY GALVANO-MAGNETISM.

Meanwhile the rapid awakening of attention among physicists to the magnetic relation of the galvanic current, and the production of the galvanometer, at once indicated a new and promising method of signaling to a distance by galvanic agency.

The Galvanometer.—In 1820, Hans Christian Oersted, professor of natural philosophy at Copenhagen, announced through various European journals his discovery that if a straight conjunctive wire through which a galvanic current is passing "be placed horizontally above the magnetic needle and parallel to it . . . the needle will be moved, and the end next the negative side of the battery will go westward. . . . If the uniting wire be placed in a horizontal plane *under* the magnetic needle all the effects are the same as when it is above the needle, only they are in an opposite direction."§

Although the directive influence of a galvanic conductor on a mag-

* *Practical Mechanic and Engineers' Magazine*, June, 1846, vol. i, 2d series, pp. 239, 240.

† *English patent* of A. Bain, Dec. 12, 1846, No. 11480.

‡ *American patent* of S. F. B. Morse, May 1, 1849, No. 6420.

§ Thomson's *Annals of Philosophy*, Oct. 1820, vol. xvi, pp. 274, 275. (Also, *Journal de Physique*, etc. 1820, vol. xci, pp. 72–76; *Annales de Chimie et de Physique*, 1820, vol. xiv, pp. 417–425; *Bibliothèque Universelle des Sciences*, etc. 1820, vol. xiv, pp. 274–284; *Annales Générales des Sciences Physiques*, 1820, vol. v, pp. 259–264; Gilbert's *Annalen der Physik*, 1820, vol. lxvi, pp. 295–304; Schweigger's *Journal für Chemie und Physik*, 1820, vol. xxix, pp. 275–281; *Giornale Arcadico di Scienze*, etc. 1820, vol. viii, pp. 174–178; Brugnatelli's *Giornale di Fisica*, etc. 1820, pp. 335–342.)

netic needle, was observed and announced by an Italian savant, Gian Domenico Romagnosi, of Trent, at the beginning of the present century, (shortly after the production of the galvanic battery by Volta,) this important phenomenon attracted no attention, and produced no results, until it was republished two decades later by the Danish physicist.*

In the same year—almost immediately after Oersted's announcement, Prof. Johann S. C. Schweigger, of Halle, made a great improvement on his galvano-magnetic indicator (of a single wire circuit), by giving the insulated wire a number of turns around an elongated frame longitudinally inclosing the compass-needle, and by thus multiplying the effect of the galvanic circuits upon the sensibility of the needle converted it into a real *measuring* instrument,—a "galvanometer."†

This delicate indicator at once suggested a new mode of galvanic telegraphing. In a memoir read to the "Royal Academy of Sciences," at Paris, October 2, 1820, André Marie Ampère, affirming "the possibility of deflecting a magnetic needle at a great distance from the pile, through a very long conducting wire," remarked: "This experiment, suggested to me by the illustrious Laplace, was completely successful. . . . From the success of the experiment" he added, "it is feasible by means of as many conducting wires and magnetic needles as there are letters, (each letter being assigned to a separate needle,) and by help of a battery at a distance, with its poles alternately connected with the extremities of each conductor, to establish a kind of telegraph adapted to transmit over intervening obstacles whatever information may be desired to the person observing the letters of the needles. A set of keys near the battery, bearing corresponding letters and making connection by their depression, would offer a facile means of correspondence; re-

*As early as 1802, eighteen years before Oersted's discovery, M. Romagnosi, a publicist and physicist of Trent, observed the deflection of the magnetic needle when placed near a parallel conductor of the galvanic current. An account of this discovery was published in the *Gazzétta di Trento*, August 3, 1802. See "Supplement," NOTE B.

† "Additions to Oersted's Electro-magnetic Experiments," a memoir read at the *Naturforschenden Gesellschaft* at Halle, September 16 and November 4, 1820. An abstract of this paper was published in the *Allgemeine Literatur-Zeitung* of Halle, (4to,) November, 1820, No. 296, vol. iii, col. 621–624. The full memoir appeared in the *Journal für Chemie und Physik*, 1821, vol. xxxi, pp. 1–17; and "Additional Remarks," etc. by Dr. Schweigger, in the same volume, pp. 35–41.

A galvanometer of somewhat different form, having a vertical helix and employing an unmagnetized needle, was very shortly afterward independently devised by Johann Christian Poggendorff, of Berlin; and as he preceded Schweigger in publishing an account of it, he is sometimes regarded as the original inventor. (*Edinburgh Philosophical Journal*, July, 1821, vol. v, p. 113.) Schweigger designated his device an "Electro-magnetic Multiplicator"; Poggendorff designated his arrangement a "Galvano-magnetic Condensator." Professor Oersted remarks, "Immediately after the discovery of electro-magnetism, M. Schweigger, professor at Halle, invented an apparatus admirably adapted for exhibiting by means of the magnetic needle, the feeblest electric currents. . . . M. Poggendorff, a distinguished young savant of Berlin, constructed an electro-magnetic multiplier very shortly after M. Schweigger, with which he made some striking experiments. M. Poggendorff's work having been cited in a book on electro-magnetism by the celebrated M. Ernan, (published immediately after the discovery of these phenomena,) became known to several philosophers before that of M. Schweigger." (*Annales de Chimie et de Physique*, 1823, vol. xxii, pp. 358–360.)

quiring only the time to touch each key at the one station, and to read each letter at the other."*

Ingenious as this early proposal of an electro-magnetic telegraph appears, it really presents essentially but the substitution of the new-found galvanometer for the old electrometer at the receiving station, as first employed by Lesage, nearly half a century previously.

1823. The first to develop practically, Ampère's suggestion of a galvanometer telegraph, was the Russian Baron Paul Ludovitsch Schilling, of Cronstadt. The personal friend of Sœmmering, he became from an early date warmly interested in the galvanic telegraph; and not long after Schweigger's invention of the galvanometer, he appears to have commenced his experiments in the direction pointed out by Ampère. His countryman, the venerable Dr. Hamel, of St. Petersburg, who enjoyed his acquaintance, gave in 1859, in his "Historical account of the introduction of the galvanic and electro-magnetic Telegraph," the following interesting particulars of Schilling's early associations and pursuits:†

"At the time when Sœmmering became a member of the Academy of Sciences at Munich, in 1805, there was attached to the Russian embassy in that capital, the Baron Pavel Ludovitsch Schilling, of Cronstadt. About a year after the invention of the telegraph [by the former] Schilling saw experiments performed with it. He was so forcibly struck with the probability of a very great usefulness of the invention that from that day galvanism and its applications became one of his favorite studies."

"In the spring of 1812, Baron Schilling was endeavoring to contrive a conducting cord sufficiently insulated that it might convey the galvanic current not only through wet earth, but also through long distances of water. The war then impending between France and Russia made Baron Schilling desirous of finding a means by which such a conducting cord should serve for telegraphic correspondence between fortified places and the field, and likewise for exploding powder mines across rivers. . . . In the autumn of 1812, he actually exploded powder mines across the river Neva, near St. Petersburg. . . . Baron Schilling has told me that during his stay at Paris, he with his subaqueous conductor, several times (to the astonishment of the lookers-on) ignited gunpowder across the river Seine."

"On the 29th of December, 1815, there came to pay his respects to Sœmmering (while Baron Schilling was just with him) the well-known natural philosopher Johann Salomon Chistian Schweigger, then professor of natural philosophy and chemistry at the Physico-technical Institute at Nuremberg, who was on his way to Paris and London: (in which

* *Annales de Chimie et de Physique*, 1820, vol. xv, pp. 72, 73.

† The writer states: "Letters show that the cordial friendship between Sœmmering and Baron Schilling continued unchanged to the time of his decease in 1830." Schilling died August 7, 1837. Dr. Hamel himself had the fortune to be personally acquainted with Oersted, Schweigger, Ampere, Arago, Sœmmering, Schilling, and other electro-magnetic and telegraphic celebrities.

latter place I had afterward the pleasure of making his acquaintance.) . . . Baron Schilling having made at Sœmmering's the acquaintance of Schweigger, of course could not forsee that one day an invention of this gentleman, the 'multiplier,' would enable him to make at St. Petersburg, the first electro-magnetic telegraph."*

It is impossible, in the scarcity of documentary evidence, to ascertain at what date Schilling's long contemplated project of a galvanometer telegraph (designed as an improvement on the galvanic telegraph of his friend Sœmmering) was first reduced to a practical or working form: but it was at least as early as the year 1823, when Schilling constructed at St. Petersburg an electro-magnetic telegraph apparatus whose signals were produced by five galvanometer needles, each provided with its own independent galvanic circuit. Schilling was enabled to effect his great simplification of an original alphabet of circuits, by the ingenious expedient of giving to each needle a positive and negative motion by means of reversed currents, and then of combining two or more of these signals. Whether this was really Schilling's first form of apparatus is very doubtful; but it is at least certain that he exhibited an operative instrument before the Emperor Alexander in 1824, or in 1825.†

Dr. Hamel remarks: "It was reserved for Baron Schilling at St. Petersburg to make the first electro-magnetic telegraph. Having become (as we know) through Sœmmering, at Munich, passionately fond of the art of telegraphing by means of galvanism, he now used for it the deflection of the needle. which he placed within the 'multiplier' of Schweigger horizontally on a light vertical axle hanging on a silken thread, and bearing a circular disk of paper colored differently on each side. . . . By degrees he simplified the apparatus. For a time he used five needles, and at last he was able to signalize even with one single needle and multiplier, producing by a combination of movements in the two directions, all the signs for letters and numbers. Having known Sœmmering's alarum, Schilling invented one for his telegraph also. His success in bringing his instruments to a high state of perfection would have been much more rapid had his time not been so much occupied with various duties, and particularly with the founding and directing of a large lithographic establishment for the Russian Government. Baron Schilling's telegraph was an object of great curiosity at St. Petersburg; it was frequently exhibited by him to individuals and to parties. Already the Emperor Alexander I, had been pleased to notice it in its earlier stage, and when it was reduced to great simplicity, his Majesty the Emperor Nicholas honored Baron Schilling on the 13th of March, 1830, with a visit at his lodgings in Opotchinin's house, in the Konooshennaja, to see experiments performed with it through a great length of conducting wires. . . .

"In May of the last-mentioned year (1830) Baron Schilling undertook a journey to China. . . . After his return from the borders of China to

*Journal of the Society of Arts, July 22, 1859, vol. vii, pp. 597, 598.

†The Emperor Alexander died in 1825.

St. Petersburg, in March, 1832, Baron Schilling occupied himself again with the telegraph, and in May, 1835, he undertook a journey to the west of Europe, taking his simplified instrument with him. In the month of September he attended the meeting of the German physicists at Bonn on the Rhine, where on the 23d he exhibited his telegraph before the section of natural philosophy and chemistry, over which Professor Georg Wilhelm Muncke, of the University of Heildelberg, presided. Muncke was much pleased with Schilling's instrument, and he determined at once to get one for exhibition at his lectures. I have lately found at Heidelberg . . . in a store-room, the apparatus which Professor Muncke got made in imitation of the one exhibited by Baron Schilling at Bonn." *

The conflicting accounts of Schilling's system given at a later date appear to refer to instruments constructed at different periods. Thus it is said that in the latter part of 1832 [!] he used a "certain number of platinum wires insulated and united in a cord of silk, which put in action, by the aid of a species of key, 36 magnetic needles, each of which was placed vertically in the center of a multiplier. M. de Schilling was the first who adapted to this kind of apparatus an ingenious mechanism suitable for sounding an alarm, which when the needle was turned at the beginning of the correspondence, was set in play by the fall of a little ball of lead which the magnetic needle caused to fall. This telegraph of M. de Schilling was received with approbation by the Emperor, who desired it established on a larger scale: but the death of the inventor postponed the enterprise indefinitely." †

It is also stated in another account, that Schilling exhibited his telegraphic instruments before the Emperor Alexander. "In order to apprise the attendant before the commencement of a telegraphic dispatch, Schilling set off an alarm. How much of his apparatus belongs properly to the Baron Schilling, or whether a part of it was not an imitation of that of Gauss and Weber, is not for the editor to decide; but that Schilling had already experimented (probably with a more imperfect apparatus) before the Emperor Alexander, and subsequently before the Emperor Nicholas, is affirmed by the authorities adduced." The account describes the communications as consisting of signs devised from the various combinations of the right and left deflections of the single nee-

* *Journal of the Society of Arts*, July 29, 1859, vol. vii, pp. 606, 607. The apparatus above referred to, is noteworthy as being that seen by Mr. William Fothergill Cooke on attending one of the lectures by Professor Muncke, at Heidelberg, March 6, 1836, on the electro-magnetic telegraph; and which apparatus he proceeded immediately to have reproduced. Returning to London April 22, of the same year, Mr. Cooke, (in conjunction with Professor Wheatstone,) succeeded by his energy in introducing the needle telegraph into England: and thus Schilling's great invention became transplanted from St. Petersburg to London, without either of its English introducers having any idea of its true origin. As Dr. Hamel remarks: "Mr. Cooke, who had never occupied himself with the study either of natural philosophy in general, or of electricity in particular, did not at all get further acquainted with Professor Muncke. He did not even acquire his name properly: he calls him Möncke. He had no idea that the apparatus he had seen had been contrived by Baron Schilling in Russia."

† *Report* of the "Academy of Industry," Paris, February, 1839.

dle.* It must evidently have been at a later date than 1825 when Schilling reduced his telegraph line to a single circuit of two wires and employed but a single galvanometer. Whether Schilling or Gauss was the original inventor of that most important improvement in galvanic telegraphy, the simplification and reduction of the line of communication to a single circuit cannot now perhaps be definitely determined;† but that the credit belongs to Schilling seems highly probable. That Schilling first invented and constructed a practical and operative electro-magnetic telegraph apparatus is placed beyond dispute; although the historical evidences of actual date are somewhat obscure. It is remarkable that although Schilling's early experimental telegraph was widely exhibited, and to numbers of distinguished visitors, no contemporary publication of its character or construction was made; and the invention was unknown to Western Europe for a dozen years later.‡

Thus, in 1829, Gustav Theodor Fechner, of Leipsic, evidently quite unaware of Schilling's labors—years before, wrote in a text-book on Galvanism: "There is no doubt that if the insulated wires of twenty-four multipliers, representing the letters of the alphabet (situated in Leipsic, for example), were conducted underground to Dresden, where should be placed a battery, we would have thereby a medium of communication probably not very expensive, through which intelligence could be instantaneously transmitted from one city to another."§

And in the year following, 1830, Dr. William Ritchie, at London, in a lecture before the Royal Institution on the evening of February 12, exhibited a working model of a telegraph provided with 26 circuits of wire for the several letters of the alphabet, "Mr. Ritchie concluded by exhibiting the electro-magnetic telegraph proposed by Ampère, by means of which, rapid communication might be carried on between towns in every state of the weather. The lecturer concluded by observing that in the present state of the inquiry, we cannot pronounce with absolute certainty with regard to the success of this ingenious project."‖

The Electro-Magnet.—But almost simultaneously with the birth of the galvanometer, this fertile agent—electricity,—developed a new and no less

* *Polytechnisches Central-Blatt*, June, 1838, Jahrgang iv. b. i, p. 486.

† One of the foremost of telegraphic inventors, and the personal friend of Gauss, Steinheil himself, speaks thus uncertainly on this subject: "The experiments instituted by Schilling by the deflection of a single magnetic needle, seem much better contrived [than Ampère's plan of an alphabet of wires, adopted by Mr. Davy and others]; he did not, however, succeed in surmounting the mechanical difficulties that attend the question in this shape . . . Gauss, and probably in imitation of him, Schilling . . . made use of but a single wire running to the distant station and back." (Sturgeon's *Annals of Electricity*, etc. March, 1839, vol. iii, pp. 448 and 450.)

‡ In 1835, Schilling, assisted by Baron Jacquin and Professor Ettingshausen, experimented with telegraph wires extended over the houses and across the streets of Vienna, preferring air lines to conductors laid in the earth. In 1837, Schilling ordered at a rope manufactory in St. Petersburg the necessary length of an insulated submarine cable, for the purpose of connecting telegraphically that capital with Cronstadt, through a portion of the Gulf of Finland: the distance between the two cities being twenty miles. His death which occurred August 7, 1837, arrested the enterprise.

§ *Lehrbuch des Galvanismus*, etc. by G. F. Fechner, 8vo. Leipzig, 1829, p. 269.

‖ *The Quarterly Journal* of the Roy. Inst. of Gr. Brit. Mar. 1830, vol. xxix, p. 185.

marvelous progeny. In the same year, 1820, Dominique François Arago, of Paris, announced, "On repeating the experiments of the Danish physicist, I have observed that the same current will *develop* strongly in strips of iron or steel, the magnetic power. . . . The conjunctive wire communicates to soft iron but a momentary magnetization; but to small pieces of steel it gives frequently a permanent magnetism. I have been able thus to completely magnetize sewing needles."*

This germ of a new power required, as usual, the successive labors of more than one philosophic investigator to develop fully its capacities. To William Sturgeon, of Woolwich, England, belongs the distinguished honor (too little appreciated by his countrymen) of giving to the scientific toy of Arago a suitable form, and thus of first producing in 1824, the true electro-magnet with its intermittent control of an armature. Dispensing with the glass tube of Arago, Sturgeon constructed a horse-shoe bar of soft iron (after the form of the usual permanent magnet), which he coated with a non-conducting resinous varnish. Then winding a copper wire in a loose coil directly about the limbs of the horse-shoe, on bringing the ends of the wire in connection with the poles of a single galvanic pair of moderate size, he found his temporary magnet capable of sustaining several pounds by its armature; and on breaking the circuit, becoming instantly powerless.

It resulted from the correlative function of the galvanic current in directing transversely a permanently magnetized needle (first discovered by Romagnosi and Oersted), or in inducing temporary magnetism in iron thus transversely placed (first discovered by Arago and Sturgeon), that two distinct methods of signaling were offered by this new agency, accordingly as a permanent or a temporary magnet were employed. In the former case, the determined oscillations of the *magnetic bar*, by means of intermittent currents in a surrounding coil, would form the indicating device; and in the latter case, the determined oscillations of the *armature*, by means of intermittent currents in the coil surrounding its associated magnet, would give the indication. Hence the two types of electro-magnetic telegraph: the magnetic-needle system, and the magnetic-armature system.†

On experimenting with the galvanometer needle, it was very soon discovered that it responded only to variations of surface action in a single pair of galvanic elements, and that a large number of galvanic cells (as in the Cruickshanks battery), having even a greater total surface of oxi-

* *Annales de Chimie et de Physique*, 1820, vol. xv, pp. 93, 95, Arago's method of experimentation consisted in winding the wire connecting the poles of the battery, around a glass tube in a loose helix, within which tube small pieces of iron or steel were placed. Sir Humphrey Davy, of England, not long afterward, also magnetized steel-needles by galvanism; and even effected the result with ordinary electricity from a Leyden-jar battery. (*Annals of Philosophy*, August, 1821, vol. ii, n. s. pp. 81–88.) This was the germ—though scarcely more than the germ—of the electro-magnet. For a notice of early anticipations of electro-magnetism, see "Supplement," NOTE C.

† A modification of the latter system, by which the oscillations of an armature are superseded by the variable attraction between the magnetized core and its hollow galvanic coil, might perhaps be considered as forming a third type—that of the "axial" magnet. This has been employed in House's printing telegraph.

dation, produced but a comparatively small declination of Schweigger's needle. In fact, no multiplication of galvanic elements was successful in increasing the deflection of a given galvanometer. On the other hand, the same galvanometer was found to have its deflections greatly reduced with every increase in the length of the interposed circuit. And here again an increase of surface in the galvanic pair failed to overcome the increased resistance of a lengthened conductor. There was also an early limit found to the number of turns in the galvanometer coil, which could be efficiently employed with any given surface of oxidizable metal in the single galvanic element.

In 1824, Peter Barlow, the eminent English mathematician and magnetician, taking up Ampère's suggestion, endeavored more fully to test its practicability. He has thus stated the result: "In a very early stage of electro-magnetic experiments, it had been suggested that an instantaneous telegraph might be established by means of conducting wires and compasses. The details of this contrivance are so obvious, and the principle on which it is founded so well understood, that there was only one question which could render the result doubtful; and this was, is there any dimunition of effect by lengthening the conducting wire? It has been said that the electric fluid from a common [tin-foil] electrical battery had been transmitted through a wire four miles in length without any sensible diminution of effect, and to every appearance instantaneously; and if this should be found to be the case with the galvanic circuit, then no question could be entertained of the practicability and utility of the suggestion above adverted to. I was therefore induced to make the trial; but I found such a sensible diminution with only 200 feet of wire, as at once to convince me of the impracticability of the scheme. It led me however to an inquiry as to the cause of this diminution and the laws by which it is governed."*

From the rapid reduction of effect observed with increasing lengths of conjunctive wire under the conditions tried. Barlow (from a considerable series of experimental results) was led to believe that the resistance of the conducting wire is approximately proportional to the square root of its length.†

Notwithstanding therefore Ampère's "completely successful" experiment "through a very long conducting wire" and Schilling's later working of his telegraph "through a great length of wires," (the precise length of the circuit not being stated in either case,) the problem of the electro-magnetic telegraph could hardly be considered as satisfactorily solved for any practical purposes of communicating to great distances. In the deliberate judgment of one of the most eminent of English phys-

* "On the laws of electro-magnetic action." *Edinburgh Philosophical Journal*, Jan. 1825, vol. xii, p. 105.

† Pp. 110, 111 of the Journal just cited. Later experiments under varied conditions have shown that Ohm's law (announced three years after Barlow's) of a simple ratio of resistance to length is approximately correct.

icists in this special department, careful experiment only tended to show "the impracticability of the scheme."

It is at this point that there appears a new explorer in the electro-magnetic field: a field from which apparently all the laurels had been already gathered. Joseph Henry, elected to the professorship of mathematics and natural philosophy in the Albany Academy, of New York, in 1826, commenced very shortly afterward his scientific investigations. Sturgeon, in 1824, had pointed out the proper manner of making an "electro-magnet," and had also greatly improved lecture-room apparatus for illustrating the torsional reaction between a permanent magnet and a galvanic circuit when either is made movable. By introducing in such cases a larger and more powerful magnet he had succeeded in exhibiting the usual phenomena on a larger scale with a considerable reduction of the battery power.*

Henry was enabled by his skillful experimental investigations to exhibit all the class illustrations attempted by Sturgeon, not only on a still larger and more conspicuous scale, with the use of feeble magnets (where required), but with a still further reduction of the battery power. And he moreover carried out the same results to other cases where an artificial magnet is inapplicable, as for example, in the illustration of Ampère's fine discovery of the mutual action of two electric currents on each other, or of the influence of the terrestrial magnetism on a current, as in Ampère's swinging galvanic ring, or the floating ring of De La Rive. These very striking and unexpected results were obtained by the simple expedient of adopting in every case where single circuits had previously been used, the manifold coil of fine wire which Schweigger had employed to increase the sensibility of the galvanometer.

The coils employed by Henry in the various articles of apparatus thus improved, comprised usually about twenty turns of fine copper wire wound with silk to prevent metallic contact, the whole being closely bound together. To exhibit for instance Ampère's ingenious and delicate experiment showing the directive action of the earth as a magnet on a galvanic current when its conductor is free to move, (usually a small wire frame or ring, of a few inches in diameter, with its extremities dipping either into mercury cups or into mercury channels,) the effect was strikingly enhanced by Henry's method of suspending by a silk thread a large circular coil, 20 inches in diameter, of many wire circuits bound together with ribbon,—the extremities of the wire protruding at the lower part of the hoop, and soldered to a pair of small galvanic plates;—when by simply placing a tumbler of acidulated water beneath, the hoop

* *Transactions of the Society for the encouragement of Arts*, etc. 1825, vol. xliii, pp. 38–52. Sturgeon's battery (of a single element) consisted "of two fixed hollow concentric cylinders of thin copper, having a movable cylinder of zinc placed between them. Its superficial area is only 130 square inches, and it weighs no more than 1 lb. 5 oz." Mr. Sturgeon was deservedly awarded the silver medal of the Society for the Encouragement of Arts, &c. "for his improved electro-magnetic apparatus." The same is described also in the *Annals of Philosophy*, Nov. 1826, vol. xii, n. s. pp. 357–361.

at once assumed (after a few oscillations) its equatorial position transverse to the magnetic meridian. Such was the character of demonstration by which the new Professor was accustomed to make visible to his classes the principles of electro-magnetism. And it is safe to say that in simplicity, efficiency, and conspicuous distinctness, such apparatus for the lecture-room was far superior to any of the kind then existing.

The details of this early contribution to electrical science were set forth in a communication read by Henry before the Albany Institute October 10, 1827, "On some modifications of the electro-magnetic apparatus." In this paper he remarks:

"Mr. Sturgeon, of Woolwich, who has been perhaps the most successful in these improvements, has shown that a strong galvanic power is not essentially necessary even to exhibit the experiments on the largest scale. . . . Mr. Sturgeon's suite of apparatus, though superior to any other as far as it goes, does not however form a complete set: as indeed it is plain that his principle of strong magnets cannot be introduced into every article required, and particularly into those intended to exhibit the action of the earth's magnetism on a galvanic current, or the operation of two conjunctive wires on each other. To form therefore a set of instruments on a large scale that will illustrate all the facts belonging to this science, with the least expense of galvanism, evidently requires some additional modification of the apparatus, and particularly in those cases in which powerful magnets cannot be applied. And such a modification appears to me to be obviously pointed out in the construction of Professor Schweigger's galvanic 'multiplier'; the principles of this instrument being directly applicable to all the experiments in which Mr. Sturgeon's improvement fails to be useful."*

Should any one be disposed to conclude that this simple extension of Schweigger's multiple coil was unimportant and unmeritorious, the ready answer occurs, that talented and skillful electricians, laboring to attain the result, had for six years failed to make such an extension. Nor was the result by any means made antecedently assured by Schweigger's success with the galvanometer. If Sturgeon's improvement of economizing the battery size and consumption, by increasing the magnet factor (in those few cases where available), was well deserving of reward, surely Henry's improvement of a far greater economy, by increasing the circuit factor (entirely neglected by Sturgeon), deserved a still higher applause.

In a subsequent communication to Silliman's Journal, Henry remarks on the results announced in October, 1827: "Shortly after the publication mentioned, several other applications of the coil, besides those described in that paper, were made in order to increase the size of electro-magnetic apparatus, and to diminish the necessary galvanic power. The most interesting of these was its application to a development of magnetism in soft iron, much more extensive than to my knowledge had been

* *Transactions of the Albany Institute,* vol. i, pp. 22, 23.

previously effected by a small galvanic element." And in another later paper, he repeated to the same effect: "After reading an account of the galvanometer of Schweigger, the idea occurred to me that a much nearer approximation to the theory of Ampère could be attained by insulating the conducting-wire itself, instead of the rod to be magnetized; and by covering the whole surface of the iron with a series of coils in close contact."

The electro-magnet figured and described by Sturgeon (in his communication of November, 1825,) consisted of a small bar or stout iron wire bent into a ∩ or horse-shoe form, having a copper wire wound loosely around it in eighteen turns, with the ends of the wire dipping into mercury-cups connected with the respective poles of a battery having 130 square inches of active surface. This was undoubtedly the most efficient electro-magnet then in existence.

In June of 1828, Henry exhibited to the Albany Institute a small-sized electro-magnet closely wound with silk-covered copper wire about one-thirtieth of an inch in diameter. By thus insulating the conducting wire, instead of the magnetic bar or core, he was enabled to employ a compact coil in close juxtaposition from one end of the horse shoe to the other, obtaining thereby a much larger number of circuits, and with each circuit more nearly at right angles with the magnetic axis. The lifting power of this magnet is not stated, though it must obviously have been much more powerful than the one described by Sturgeon.

In March of 1829, Henry exhibited to the Institute a somewhat larger magnet of the same character. "A round piece of iron about one-quarter of an inch in diameter was bent into the usual form of a horse-shoe, and instead of losely coiling around it a few feet of wire, as is usually described, it was tightly wound with 35 feet of wire covered with silk, so as to form about 400 turns: a pair of small galvanic plates which could be dipped into a tumbler of diluted acid, was soldered to the ends of the wire, and the whole mounted on a stand. With these small plates the horse-shoe became much more powerfully magnetic than another of the same size and wound in the usual manner, by the application of a battery composed of 28 plates of copper and zinc each 8 inches square." In this case the coil was wound upon itself in successive layers.

To Henry, therefore, belongs the exclusive credit of having first constructed the magnetic "spool" or "bobbin," that form of coil since universally employed for every application of electro-magnetism, of induction, or of magneto-electrics.

In the latter part of 1829, Henry still further increased the magnetic power derived from a single galvanic pair of small size, by a new arrangement of the coil. "It consisted in using several strands of wire each covered with silk, instead of one." Employing a horse-shoe formed from a cylindrical bar of iron half an inch in diameter and about ten inches long, wound with 30 feet of tolerably fine copper wire, he found

that with a current from only two and a half square inches of zinc, the magnet held 14 pounds.* Winding upon its arms a second wire of the same length (30 feet) whose ends were similarly joined to the same galvanic pair, the magnet lifted 28 pounds. On these results he remarks:

"These experiments conclusively proved that a great development of magnetism could be effected by a very small galvanic element, and also that the power of the coil was materially increased by multiplying the number of wires, without increasing the length of each. The multiplication of the wires increases the power in two ways: first, by conducting a greater quantity of galvanism, and secondly, by giving it a more proper direction; for since the action of a galvanic current is directly at right angles to the axis of a magnetic needle, by using several shorter wires we can wind one on each inch of the length of the bar to be magnetized, so that the magnetism of each inch will be developed by a separate wire. In this way the action of each particular coil becomes directed very nearly at right angles to the axis of the bar, and consequently the effect is the greatest possible. This principle is of much greater importance when large bars are used. The advantage of a greater conducting power from using several wires might in a less degree be obtained by substituting for them one large wire of equal sectional area; but in this case the obliquity of the spiral would be much greater, and consequently the magnetic action less."†

But in the following year, 1830, Henry pressed forward his researches to still higher results. Assisted by his friend Dr. Philip Ten-Eyck, he proceeded to test the power of electro-magnetic attraction on a larger scale. "A bar of soft iron 2 inches square and 20 inches long was bent into the form of a horseshoe 9½ inches high; (the sharp edges of the bar were first a little rounded by the hammer;) it weighed 21 pounds. A piece of iron from the same bar, weighing 7 pounds, was filed perfectly flat on one surface for an armature or lifter. The extremities of the legs of the horse-shoe were also truly ground to the surface of the armature. Around this horse-shoe 540 feet of copper bell-wire were wound in nine coils of 60 feet each; these coils were not continued around the whole length of the bar, but each strand of wire (according to the principle before mentioned) occupied about two inches and was coiled several times backward and forward over itself. The several ends of the wires were left projecting, and all numbered, so that the first and the last end of each strand might be readily distinguished. In this manner we formed an experimental magnet on a large scale, with which several combinations of wire could be made by merely uniting the different projecting ends. Thus if the second end of the first wire be soldered to the first end of the second wire, and so on through all the series, the whole will form a continued coil of one long wire. By solder-

* It must not be forgotten that at the time when this experimental magnet was made, the strongest electro-magnet in Europe was that of Sturgeon, capable of supporting 9 pounds, with 130 square inches of zinc surface in the battery.

† Silliman's *Am. Journal of Science*, Jan. 1831, vol. xix, p. 402.

ing different ends, the whole may be formed into a double coil of half the length, or into a triple-coil of one-third the length, &c. The horse-shoe was suspended in a strong rectangular wooden-frame 3 feet 9 inches high and 20 inches wide."

Two of the wires (one from each extremity of the legs) being joined together by soldering, so as to form a single circuit of 120 feet, with its extreme ends connected with the battery, produced a lifting-power of 60 pounds. (Experiment 19.) The same two wires being separately connected with the same battery (forming a double circuit of 60 feet each), a lifting-power of 200 pounds was obtained, (Experiment 10,) or more than three times the power of the former case with the same wire. Four wires (two from each extremity of the legs) being separately connected with the battery (forming four circuits) gave a lifting-power of 500 pounds. (Experiment 12.) Six wires (three from each leg) united in three pairs (forming three circuits of 180 feet each) gave a lifting-power of 290 pounds. (Experiment 18.) The same six wires being separately connected with the battery in six independent circuits, produced a lifting-power of 570 pounds, (Experiment 13,) or very nearly double that of the same wires in double-lengths. When all the nine wires were separately attached to the battery a lifting-power of 650 pounds was evoked. (Experiment 14.) In all these experiments "a small single battery was used, consisting of two concentric copper cylinders, with zinc between them: the whole amount of zinc-surface exposed to the acid from both sides of the zinc was two-fifths of a square foot; the battery required only half a pint of dilute acid for its submersion."

"In order to ascertain the effect of a very small galvanic element on this large quantity of iron, a pair of plates *exactly one inch square* was attached to all the wires: the weight lifted was 85 pounds." (Experiment 16.) For the purpose of obtaining the maximum attractive power of this magnet, with its nine independent coils, "a small battery formed with a plate of zinc 12 inches long and 6 wide, and surrounded by copper, was substituted for the galvanic element used in the former experiments: the weight lifted in this case was 750 pounds." (Experiment 15.) *

Although not directly connected with the purpose of this exposition,

* Silliman's *Am. Jour. Sci.* same vol. pp. 404, 405. The only European physicist who at this period had obtained any magnetic results even *approaching* those effected by Henry, was Dr. Gerard Moll (professor of natural philosophy in the University of Utrecht), who having seen in England in 1828 an electro magnet of Sturgeon's which supported nine pounds (the very year in which Henry had exhibited a much more powerful magnet before the Albany Institute), "determined to try the effect of a larger galvanic apparatus"; and in 1830 remarked, "I obtained results which appear astonishing." Having formed a horse-shoe about twelve and a half inches in height, of a round bar of iron two and a quarter inches in diameter, he surrounded it with about 26 feet of insulated copper wire one-eighth of an inch thick, in a tolerably close coil of 44 turns. The weight of the whole was about 26 pounds; and with the current from a galvanic pair of about 11 square feet of zinc surface, the magnet sustained a weight of 154 pounds. (Brewster's *Edinburgh Journal of Science*, Oct., 1830, vol. iii, n. s. p. 214.) Henry's magnet less in size and weight, lifted about five times this load, with only one-eleventh of Moll's battery surface.

it may be added here that in the following year, 1831, Henry constructed for the laboratory of Yale College a magnet about one foot high from a three inch octagonal bar of iron thirty inches long, which wrapped with twenty-six strands of copper wire and excited by a battery surface of about five square feet, supported 2,300 pounds. Professor Silliman wrote on this occasion, "He has the honor of having constructed by far the most powerful magnets that have ever been known; and his last, weighing (armature and all) but 82½ pounds, sustains over a ton. It is eight times more powerful than any magnet hitherto known in Europe."* And Sturgeon (if not the real father, at least the true foster-father, of the electro-magnet), with a generous enthusiasm, remarked: "Professor Henry has been enabled to produce a magnetic force which totally eclipses every other in the whole annals of magnetism; and no parallel is to be found since the miraculous suspension of the celebrated oriental impostor in his iron coffin."†

But to return to his investigations of 1830, Henry, after finding that the highest attractive power of the magnet was developed by his novel artifice of multiple coils, proceeded to experiment with the simple spool magnet of long continuous single coil; and his researches were rewarded by a new discovery, namely that though the former method of winding the magnet produced the strongest attraction, the latter arrangement (under special conditions) permitted the weaker attractive power to be exercised at a far greater distance; that is through a much greater length of conducting wire.

Employing his earlier and smaller magnet of 1829, formed of a quarter-inch rod, but wound with about 8 feet of copper wire, he tried the effects of different battery powers, of different length of circuits, and of different lengths of coil upon the magnet. Excited with a single pair, "composed of a piece of zinc plate 4 inches by 7, surrounded with copper" (about 56 square inches of zinc surface), the magnet sustained four and a half pounds. (Experiment 4.) With about 500 feet of insulated copper wire (.045 of an inch in diameter) interposed between the battery and the magnet, its lifting-power was reduced to two ounces; (Experiment 5;) or about 36 times. With double this length of wire (or a little over 1,000 feet) interposed, the lifting-power of the magnet was only half an ounce; (Experiment 4;) thus fully confirming the results obtained by Barlow with the galvanometer; and showing that the same conditions of enfeebled action with increasing length of circuit applied equally to the magnet. With a small galvanic pair 2 inches square, acting through the same length of wire, (over 1,000 feet,) "the magnetism was scarcely observable in the horse-shoe." (Experiment 3.)

Employing next a trough battery of 25 pairs, having the same zinc surface as previously, the magnet in direct connection, (which before had supported four and a half pounds,) now lifted but seven ounces; not

*Silliman's *Am. Jour. Sci.* April, 1831, vol. xx, p. 201.

†*Philosophical Magazine; and Annals*, March, 1832, vol. xi, p. 199.

quite half a pound. But with the 1,060 feet of copper wire (a little more than one fifth of a mile) suspended several times across the large room of the academy, and placed in the galvanic circuit, the same magnet sustained eight ounces: (Experiment 7:) that is to say, the current from the galvanic trough produced greater magnetic effect through this length of wire, than it did without it.

"From this experiment it appears that the current from a galvanic trough is capable of producing greater magnetic effect on soft iron after traversing more than one-fifth of a mile of intervening wire than when it passes only through the wire surrounding the magnet. It is possible that the different states of the trough with respect to dryness may have exerted some influence on this remarkable result; but that the effect of a current from a trough if not increased is but slightly diminished in passing through a long wire is certain." And after speculating on this new and at the time somewhat paradoxical result, Henry concludes: "But be this as it may, the fact that the magnetic action of a current from a *trough* is at least not sensibly diminished by passing through a long wire, is directly applicable to Mr. Barlow's project of forming an electro-magnetic telegraph;* and it is also of material consequence in the construction of the galvanic coil. From these experiments it is evident that in forming the coil we may either use one very long wire, or several shorter ones, as the circumstances may require: in the first case, our galvanic combination must consist of a number of plates so as to give 'projectile' force; in the second, it must be formed of a single pair."†

The importance of this discovery can hardly be overestimated. The magnetic "spool" of fine wire, of a length—tens and even hundreds of times that ever before employed for this purpose,—was in itself a gift to science, which really forms an epoch in the history of electro-magnetism. It is not too much to say that almost every advancement which has been made in this fruitful branch of physics since the time of Sturgeon's happy improvement, from the earliest researches of Faraday downward, have been directly indebted to Henry's magnets.‡ By means of the Henry "spool" the magnet almost at a bound was developed from a feeble childhood to a vigorous manhood. And so rapidly and generally was the new form introduced abroad among experimenters, few of whom had ever seen the papers of Henry, that probably very few indeed have been

* Really Ampère's project, not Barlow's. In a subsequent paper Henry corrected this allusion by saying, "I called it 'Barlow's project,' when I ought to have stated that Mr. Barlow's investigation merely tended to disprove the possibility of a telegraph."

† Silliman's *Am. Jour. Sci.* Jan. 1831, vol. xix, pp. 403, 404.

‡ Both forms of the Henry magnet have found valuable applications in science. In Faraday's first electrical investigations, in the latter part of 1831, he acknowledged the merit of Henry's magnets, and in constructing his duplex helices for observing the phenomena of induction, he adopted Henry's method of winding 12 coils of copper wire each 27 feet long, one upon the other. (*Philosophical Transactions of the Royal Society*, November 24, 1831, vol. cxxii [for 1832], pp. 126 and 138. And Faraday's *Experimental Researches*, etc. vol. i, art. 6, p. 2, and art. 57, p. 15.)

aware to whom they were really indebted for this familiar and powerful instrumentality. But the historic fact remains, that prior to Henry's experiments in 1829, no one on either hemisphere had ever thought of winding the limbs of an electro-magnet on the principle of the "bobbin," and not till after the publication of Henry's method in January of 1831, was it ever employed by any European physicist.*

But in addition to this large gift to science, Henry (as we have seen) has the pre-eminent claim to popular gratitude of having first practically worked out the differing functions of two entirely different kinds of electro-magnet: the one surrounded with numerous coils of no great length, designated by him the "quantity" magnet, the other surrounded with a continuous coil of very great length, designated by him the "intensity" magnet.† The former and more powerful system, least affected by an "intensity" battery of many pairs, was shown to be most responsive to a single galvanic element: the latter and feebler system, least influenced by a single pair, was shown to be most excited by a battery of numerous elements; but at the same time was shown to have the singular capability (never before suspected nor imagined) of subtile excitation from a distant source. Here for the first time is experimentally established the important principle that there must be a proportion between the aggregate internal resistance of the battery and the whole external resistance of the conjunctive wire or conducting circuit; with the very important practical consequence, that by combining with an "intensity" magnet of a single extended fine coil an "intensity" battery of many small pairs, its electro-motive force enables a very long conductor to be employed without sensible diminution of the effect.‡ This was a very important though unconscious experimental confirmation of the mathematical theory of Ohm, embodied in his formula expressing the relation between electric flow and electric resistance, which though propounded two or three years previously, failed for a long time to attract any attention from the scientific world.§

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* Henry's "spool" magnet appears to have been introduced into France by Pouillet in 1832. See "Supplement," NOTE D.

† "In describing the results of my experiments the terms 'intensity' and 'quantity' magnets were introduced to avoid circumlocution, and were intended to be used merely in a technical sense. By the *intensity* magnet I designated a piece of soft iron so surrounded with wire that its magnetic power could be called into operation by an 'intensity' battery; and by a *quantity* magnet, a piece of iron so surrounded by a number of separate coils that its magnetism could be fully developed by a 'quantity' battery." (*Smithsonian Report* for 1857, p. 103.) These terms though generally discarded by recent writers, are still very convenient designations of the two classes of action, both in the battery and in the magnet.

‡ Beyond a certain maximum length, there is of course a decrease of power for each differing coil of the "intensity" magnet, proportioned to the increased resistance of a long conductor: but the magnetizing effect has not been found to be diminished in the ratio of its length. In a very long wire, the magnetizing influence (with a suitable "intensity" battery) appears to be inversely proportioned to the square of the length of the conductor.

§ Georg Simon Ohm, professor in physics at Munich, published at Berlin, in 1827, his "Galvanische Kette, mathematisch bearbeitet:" and in the following year, he published a supplementary paper entitled "Nachträge zu seiner mathematischen Bearbeitung der galvanischen Kette;" in Kastner's *Archiv für gesammte Naturlehre*:

Never let it be forgotten that he who first exalted the "quantity" magnet of Sturgeon from a power of twenty pounds to a power of twenty hundred pounds, was the absolute CREATOR of the "intensity" magnet; that magnet which alone is able to act at a great distance from its exciting battery;—that magnet which by very reason of its lower "quantity" is alone applicable to the uses of telegraphy.

As Professor Daniell has concisely stated the problem: "Electro-magnets of the greatest power, even when the most energetic batteries are employed, utterly cease to act when they are connected by considerable lengths of wire with the battery."*

Seven years after Henry's first experimental demonstration of this unlooked-for result, and his complete establishment of the conditions required for magnetizing iron at great distances through very long conducting wires, Prof. Charles Wheatstone, of King's College, London, having found a difficulty in signaling through four miles of wire, was enabled to work out the problem for his own telegraph, by help derived from Henry's labors. And yet he permitted his colleague, Prof. John F. Daniell, of King's College, to prefix to the passage above quoted from the excellent treatise on "Chemical Philosophy," the remarkable statement: "Ingenious as Professor Wheatstone's contrivances are, they would have been of no avail for telegraphic purposes without the investigation, *which he was the first to make*, of the laws of electro-magnets, when acted on through great lengths of wire." And this erroneous declaration was published long after Henry's "quantity" and "intensity" magnets had been employed in the experiments of European electricians; and years after Professor Wheatstone himself had formed the acquaintance of Henry, and in April, 1837, had learned from his own lips an account of his elaborate investigations and successful results.†

Whether Baron Schilling ever experimented on a sufficient length of circuit to encounter the fundamental practical difficulty announced by Barlow in 1825 does not appear; but that formidable obstacle to the actual extension of his enterprise, certainly existed until the year 1831, when Henry announced that the principles demonstrated by his researches in 1829 and 1830, were "directly applicable to the project of forming an electro-magnetic telegraph." And while these principles

(8vo. Nürnberg:) 1828, vol. xiv, pp. 475–493. Fourteen years after the publication of the former memoir, this elaborate discussion was for the first time translated into English, by Mr. William Francis. ("The Galvanic Circuit investigated mathematically." Taylor's *Scientific Memoirs*, etc. London, 1841, vol. ii, pp. 401–506.)

* *Introduction to the Study of Chemical Philosophy*, second edition, 8vo. London, 1843, chap. xvi, sect. 859, p. 576.

† *Smithsonian Report* for 1857, pp. 111, 112. The following pertinent extract is made from an excellent and appreciative memoir of the "Life and Work of Joseph Henry," recently read at the annual session of the American Electrical Society, at Chicago, Ill., December 12, 1878, by one of its vice-presidents, Mr. Frank L. Pope: "In 1856, referring again to these experiments, Wheatstone writes: 'With this law and its applications, *no persons in England*, who had before occupied themselves with experiments relating to electric telegraphs, had been acquainted.' . . . It would seem from the peculiar wording of Wheatstone's statement last quoted, that he must then have been aware of Henry's priority in this respect, and had his experiments in mind, at the time of writing it." (*Journal of the Am. Electrical Society*, vol. ii, pp. 135, 136.) This subject is more fully considered in the "Supplement," NOTE F.

underlie all subsequent applications of the intermittent magnet, they form indeed the indispensable basis of every form of the electro-magnetic telegraph since invented. They settled satisfactorily (in Barlow's phrase) the "only question which could render the result doubtful"; and though derived from the magnet, were obviously as applicable to the galvanometer needle.*

It is idle to say in disparagement of these successes, that in the competitive race of numerous distinguished investigators in the field, diligently searching into the conditions of the new-found agency, the same results would sooner or later have been reached by others. For of what discovery or invention may not the same be said? Only those who have sought in the twilight of uncertainty, can appreciate the vast economy of effort by prompt directions to the path from one who has gained an advance. Not for what might be, but for the actual bestowal, does he who first grasps a valuable truth merit the return of at least a grateful recognition.

1831. As an experimental demonstration of the telegraph—now made possible, Joseph Henry, early in the year 1831, suspended around the walls of one of the upper rooms in the Albany Academy, a mile of copper bell-wire interposed in a circuit between a small Cruickshanks battery and an "intensity" magnet. A narrow steel rod (a permanent magnet) pivoted to swing horizontally like the compass needle, was arranged so that one end remained in contact with a limb of the soft iron core, while near the opposite end of the compass rod a small stationary office-bell was placed. At each excitation of the electro-magnet, the compass rod or needle was repelled from one limb (by its similar magnetism) and attracted by the other limb, so that its free end tapped the bell. On reversing the current, the compass rod moved back to the opposite limb of the electro-magnet. This simple device the Professor was accustomed to exhibit to his classes at the academy, during the years 1831 and 1832, in illustration of the facility of transmitting signals to a distance by the prompt action of electro-magnetism.†

This memorable experimental telegraphic arrangement involved three very significant and important novelties. In the first place, it was the first electro-magnetic telegraph employing an "intensity" magnet ca-

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* When urged by a zealous friend to secure an early patent on these valuable and pregnant improvements, Henry resolutely withstood every importunity, seeming to feel that a discoverer's position and aptitude are lowered by courting self-aggrandizement from scientific truth: a self-denying generosity which characterized him throughout his life. While such disinterestedness cannot fail to excite our admiration, it may perhaps be questioned whether in this case it did not, from a practical point of view, amount to an over-fastidiousness; whether such legal establishment of ownership, shielding the possessor from the occasional depreciations of the envious, and securing by its more tangible remunerations the leisure and the means for more extended researches, would not have been to science more than a compensation for the supposed sacrifice of dignity by the philosopher. Since the date of the American patents of Wheatstone and of Morse (ten years later) several hundred patents have been granted in this country for ingenious improvements upon or modifications of the electro-magnetic telegraph, all of them necessarily dependent on Henry's original invention.

† For the testimonials of a few surviving eye-witnesses to the practical working of Henry's experimental line in 1831, and 1832, see "Supplement," NOTE E.

pable of being excited at very great distances from a suitable "intensity" battery. And there can be no doubt that a similar combination of "intensity" battery, with a very long coil galvanometer (such as had previously been found inoperative), was alone wanting to have rendered the early telegraph of Schilling a popular and commercial success.

In the second place, this experimental arrangement of Henry was the first electro-magnetic telegraph employing the armature as the signaling device; or employing the *attractive* power of the intermittent magnet, as distinguished from the *directive* action of the galvanic circuit. That is to say, it was strictly speaking the first "*magnetic* telegraph."

In the third place, it was the first *acoustic* electro-magnetic telegraph. One practical inconvenience of the "needle" system has been found to be the perfect silence of its indications; and hence in almost every case a call-alarm has been required to insure attention to its messages. In this respect the intermittent magnet presents the advantage, not merely of a greater mechanical power from the same galvanic current, and thus of a better adaptation for striking a bell at a distance, but of being in itself an audible sounder by the mere impacts of its armature.*

It is suggestive to consider for a moment how different would have been the popular estimate of Henry's labors, (and especially the *practical* estimation of subsequent patentees), if the modest discoverer and inventor had been "worldly-wise" enough to secure an early patent on these three indisputably original and most pregnant features of telegraphy:—to contest which no rival has ever appeared.†

In 1832, Henry was elected to the chair of natural philosophy in the college of New Jersey, at Princeton. In 1834, he constructed for the laboratory of this college an original and ingenious form of galvanic battery, comprising eighty-eight elements, (each having an active zinc surface of one and a half square feet,) of which any number, from a single pair upward, could be brought into action; while by means of adjustable

* It may be incidentally mentioned that early in 1831, after the satisfactory operation of the first telegraphic magnet, Henry contrived the first Electro-magnetic Engine, comprising an oscillating horizontal electro-magnetic bar, just below each end of which was secured an upright permanent magnet, the two having similar poles. The polarity of the oscillating electro-magnet was reversed at the moment of attractive contact, by automatically inverting the circuit current, and thus each of its poles was alternately attracted and repelled by its neighboring magnet. (Silliman's *Am. Journal of Science*, July, 1831, vol. xx, pp. 340-343. Henry was therefore the original inventor of the automatic pole-changer or commutator,—a device having a very wide range of useful application. The illustrious English physicist, James P. Joule, in his "Historical Sketch of the rise and progress of Electro-magnetic Engines for propelling machinery," remarks: "The improved plan by Professor Henry of raising the magnetic action of soft iron, developed new and inexhaustible sources of force which appeared easily and extensively available as a mechanical agent; and it is to the ingenious American philosopher, that we are indebted for the first form of a working model of an engine upon the principle of reciprocating polarity of soft iron by electro-dynamic agency." (Sturgeon's *Annals of Electricity*, etc. March, 1839, vol. iii, p. 430.)

† A quarter of a century afterward Henry could proudly say, "I have sought no patent for inventions, and solicited no remuneration for my labors, but have freely given their results to the world; expecting only in return to enjoy the consciousness of having added by my investigations to the sum of human knowledge, and to receive the credit to which they might justly entitle me." (*Smithsonian Report* for 1857, p. 86.)

conductors, all the positive elements could be associated together, as also all the negative ones, so as to form virtually a single pair having 132 square feet of zinc surface, or any smaller area desired. In this manner the apparatus could readily be transformed into a "quantity" battery, or an "intensity" battery, at pleasure. In the same year he constructed for the laboratory a powerful "quantity" magnet, surpassing his Yale College magnet: its lifting power, with a battery not exceeding one cubic foot in bulk, being 3,500 pounds. In the following year, 1835, he extended wires across the front campus of the college grounds, from the upper story of the library building to the philosophical hall on the opposite side, through which magnetic signals were occasionally sent, distinguished by the number of taps on the bell, as first exhibited by him four or five years earlier in the hall of the Albany Academy. Although Henry had established the fact (contrary to all the antecedent expectation of physicists) that the most powerful form of magnet—the "quantity" magnet—is not the form best adapted to distant action through an extended circuit, the ingenious idea occurred to him that he could easily combine such a system with the feebler "intensity" system, so as to produce powerful mechanical action at almost any required distance. It was simply necessary to apply to the oscillating armature of the distant "intensity" magnet a suitable prolongation so arranged as to open and close the short circuit of the adjoining "quantity" magnet of any available power. It was with his Princeton telegraph line, and its comparatively feeble magnet, that he undertook the experiment of breaking by the mere lift of a small wire from a mercury thimble the "quantity" circuit of his monster magnet, and thus causing its heavy load to fall:—a force scarcely safe if exerted through any sensible distance. He thus fully illustrated the practicability of calling into action at a great distance a power capable of producing the most energetic mechanical effects.*

1833. Ten years after the experimental telegraph of Schilling, Professors Carl Friedrich Gauss and Wilhelm Edward Weber constructed at Göttingen a galvanometer telegraph of single circuit from the Cabinet of Natural Philosophy to the Observatory, a distance of about a mile and a half. The two naked wires after the method of Weber were carried over the houses and steeples of Göttingen, being supported by insulators. The battery power being small, the receiving apparatus consisted of a "multiplier" containing a very great length of fine silvered copper wire; and the magnetic bar suspended by a silk thread carried on the axis of suspension a small mirror, whose minute deflections were observed at the distance of ten or twelve feet through a telescope.† The tele-

* *Smithsonian Report* for 1857, pp. 106, 112.

† This appears to be one of the first employments of a reflecting galvanometer, an instrument which in the hands of Sir William Thomson has been brought to an extreme degree of sensibility, and has rendered ocean telegraphy possible. As early as 1826, however, Prof. Christian J. Poggendorff applied the reflector to the magnetic needle for accurately determining minute variations in its horizontal declination. (Pogg. *Annalen der Phys. und Chem.* 1826, vol. vii. pp. 121–130.)

graph was first worked by a galvanic current from a battery, and afterward for convenience by the secondary current from a magneto-electric apparatus: to which Gauss adapted an arrangement of commutator, whereby the direction of the induced current could be instantly reversed by a touch of the finger. The alphabet of signs was made up of differing combinations of right and left deflections of the needle. Weber applied to the signaling device a delicate apparatus for setting off a clock alarm.*

1836. Prof. C. A. Steinheil, of Munich, at the request of Gauss, (who was absorbed in more abstract researches on magnetism,) in 1834, undertook to develop and improve his arrangement; and in 1836 had constructed a similar galvanometer telegraph line between Munich and Bogenhausen, a distance of about two miles.† Employing a greater power he arranged at the receiving station the magnetic bar or double bars of the galvanometer with a larger sweep, so that two bells of differing tones should be struck thereby; and he thus produced an acoustic telegraph (five years later than Henry's), capable of audible language, and dispensing with the occasion for any call-alarm. To the adjacent ends of the two magnetic bars having opposite polarities, but oscillating within the same coil, he applied fountain pens or marking-points so as to make permanent alternating dots on a fillet of paper carried under them by the regular movement of clock-work, in the manner long familiarly employed in self-registering meteorological and other instruments. Although Dyar, on Long Island, had devised a chemical register as early as 1828, and had partly executed it by a successful trial, this double magnet of Steinheil appears to constitute the earliest operative application of an automatic record to the electric, or to the electro-magnetic, telegraph. Steinheil also improved somewhat on the alphabet of Gauss, though adopting substantially the same system.‡

In the following year, 1837, he made another most important improvement in practical telegraphy, by the unexpected discovery that even the single circuit of a to and fro line could be further simplified by the suppression and economy of one-half of its wire.§

* *Göttingische Gelehrte Anzeigen*, Aug. 9, 1834, part ii, No. 128, pp. 1272, 1273. And *Polytechnisches Central-Blatt*, June, 1838, Jahrgang iv, No. 31, pp. 487–495.

† According to Dr. Hamel of St. Petersburg, in the early part of July, 1837, "Steinheil, at Munich, had completed the connection of his house in the Lerchenstrasse with the building of the Academy of Sciences, and with the Royal Observatory at Bogenhausen, by means of 36,000 feet of wire for conducting the current both ways, the wires being suspended in the air." (*Journal of Society of Arts*, July 29, 1859, vol. vii, p. 609.)

‡ Steinheil remarks: "As long as the intervals between the separate signs remain equal, they are to be taken together as a connected group, whether they be pauses between the tones, or intervals between the dots marked down. A longer pause separates these groups distinctly from each other. We are thus enabled, by appropriately selected groups thus combined, to form systems representing the letters of the alphabet, or stenographic characters, and thereby to repeat and render permanent at all parts of the chain where an apparatus like that above described is inserted, any information that we transmit. The alphabet that I have chosen represents the letters that occur the oftenest in German by the simplest signs." (Sturgeon's *Annals of Electricity*, etc. April, 1839, vol. iii, p. 520.)

§ "In 1837 Professor Steinheil operated a telegraph line between Munich and Bogen-

"Quite recently I made the discovery that the ground may be employed as one-half of the connecting chain. As in the case of frictional electricity, water or the ground may with the galvanic current form a portion of the connecting wire. Owing to the low conducting power of these bodies compared with metals, it is necessary that at the two places where the metal conductor is in connection with the semi-conductor, the former should present very large surfaces of contact. Taking water for instance to conduct two million times worse than copper, a surface of water proportional to this must be brought in contact with the copper, to enable the galvanic current to meet with equal resistance in equal distances of water and of metal: for instance, if the section of a copper wire is one-half of a square line, it will require a copper plate of 61 square feet of surface in order to conduct the galvanic current through the ground as the wire in question would conduct it: but as the thickness of the metal is quite immaterial in this case, it will be always within our reach to get the requisite surfaces of contact at no great expense. Not only do we by this means save half the conducting wire, but we can even reduce the resistance of the ground below what that of the wire would be, as has been fully established by experiments made here with the experimental telegraph."*

In his account of these valuable contributions to both the science and the art of electric telegraphy, Steinheil modestly assigns to his immediate predecessors the credit of the most important advancements in the system. He says: "To Gauss and Weber is due the merit of having, in 1833, actually constructed the first simplified galvano-magnetic telegraph. It was Gauss who first employed the excitement of induction [magneto-electricity], and who demonstated that the appropriate combination of a limited number of signs is all that is required for the transmission of communication.† Weber's discovery that a copper wire 7,460 feet long, which he had led across the houses and steeples at Göttingen, from the Observatory to the Cabinet of Natural Philosophy, required no special insulation, was one of great importance. The principle was thereby at once established of bringing the galvanic telegraph to the most convenient form. In accordance with the principles we have laid down, all that was required in addition to this was to render the signals audible; a task that apparently presented no very particular difficulty, inasmuch as in the very scheme itself a mechanical motion—namely the deflection of a

hausen, in Germany, using iron wire conductors, and the earth for a return circuit. This discovery was published in 1837, in German, and translated into English by Julian Guggsworth, November 24, 1838." (Prescott's *Hist. Electr. Telegraph*, 1860, chap. xxi, p. 405.) An account of Steinheil's telegraph was read before the French Academy of Sciences, September 10, 1838. (*Comptes Rendus*, vol. vii, pp. 590–593.)

* Steinheil's paper "On Telegraphic Communication:" translated from the German, November 24, 1838, by Julian Guggsworth. Sturgeon's *Annals of Electricity*, etc. April, 1839, vol. iii, p. 512. A full description of Steinheil's telegraph is given in Dr. Julius Dub's *Anwendung des Elektromagnetismus*, Berlin, 1863; 2d edition, 1873, sect. v. pp. 339–347.

† These statements do not however do justice to Schilling's much earlier "simplified galvano-magnetic telegraph," with which Steinheil was very imperfectly acquainted.

magnetic bar—was given. All that we had to do therefore was to contrive that this motion should be made available for striking bells or for marking indelible dots. This falls within the province of mechanics, and there are therefore more ways than one of solving the problem. Hence the alterations that I have made in the telegraph of Gauss, and by which it has assumed its present form, may be said to be founded on my perception and improvement of its imperfections, in harmony with what I had previously laid down as necessary for perfect telegraphic communication. I by no means however look on the arrangement I have selected as complete; but as it answers the purpose I had in view, it may be well to abide by it till some simpler arrangement is contrived."* To Steinheil's lasting honor be it said, that when some dozen years later "a simpler arrangement" of the receiving instrument *was* brought to his attention, he was the first to appreciate it and to urge upon the Bavarian Government its adoption, to the abandonment of a portion of his own beautiful system. An example of magnanimity, or more properly of intellectual and unbiased judgment, much rarer with inventors of practical improvements in art, than with discoverers of truth in science.

These later developments of the telegraph, though in public use at the dates specified, not having been generally described by their authors immediately for publication, were from the meager notices of them found in the foreign journals, but little known in this country for several years afterward; and hence naturally arose the strong patriotic impression with many that the electro-magnetic telegraph was essentially an American invention.

About the same time that Steinheil in Munich was engaged in improving the needle telegraph, a distinguished chemical philosopher of London, was developing the galvanic battery; and he succeeded in giving that important apparatus a uniformity and continuity of action previously unhoped for. In the adopted forms of the Voltaic battery as arranged by Cruickshanks and others, the oxygen liberated by the active zinc surface rapidly attacked the plate, forming a coating of oxide over it which soon greatly impaired its chemical and galvanic efficiency. On the other hand, the hydrogen liberated at the surface of the copper, remained largely adherent to it in the form of minute bubbles, thus insulating it to a corresponding extent from contact with the liquid; while at the same time dissolved zinc was deposited on its exposed surface.

To obviate these impediments, Professor John Frederic Daniell provided a porous partition between the two metals, which while permitting the necessary conductibility from one side to the other, prevented the convective intermixture of the separated portions of liquid, and thus also allowed for the first time two different liquids to be employed for bathing the different metals. The liquid employed on the copper side

* Sturgeon's *Annals of Electricity*, etc. Mar. 1839, vol. iii, pp. 448, 449.

was a saturated solution of the sulphate of copper:—crystals of the sulphate being suspended in the liquid, for supplying the exhaustion of the copper. The liquid on the zinc side was a very diluted sulphuric acid. With this arrangement the oxygen evolved at the zinc surface forms mainly a zinc oxide, which dissolved by the liquid into a sulphate of zinc, is prevented from passing to the copper side of the partition, and the hydrogen evolved at the copper surface combining at once with the oxygen of the copper salt, forms water, and allows the free copper to be deposited on its own plates: and Professor Daniell was able to announce in a paper read before the Royal Society of London, February 11, 1836, "I have been led to the construction of a voltaic arrangement which furnishes a constant current of electricity for any length of time which may be required."*

Although it is true that the electric telegraph may be operated by the old form of battery—frequently renewed, (just as a good steam-engine may be efficiently worked by an inferior and wasteful boiler,) and also that a uniform current well adapted to the telegraph may be obtained from the magneto-electric machine, yet the "constant" battery has proved a most valuable boon in promoting the practical economy and success of modern telegraphy.

1837. Mr. William Fothergill Cooke and Prof. Charles Wheatstone obtained an English patent June 12, 1837, (No. 7390,) for a galvanometer or needle telegraph, very similar to the earlier one of Schilling, employing six wires and five indicating needles. At what date Prof. Wheatstone's attention was first directed to electrical signaling cannot now be ascertained; but in 1834 he had undertaken by means of his ingenious invention of the revolving mirror (capable of measuring the millionth of a second), to determine the velocity of ordinary electricity through half a mile of copper wire;† and a year or two later, through about four miles of the same. Early in 1836, he had contemplated a telegraph which with five needles, should give thirty signs. Mr. W. F. Cooke, attending a lecture on electro-magnetic communication by Professor Muncke, at Heidelberg, March 6, 1836, (as previously mentioned,) at which the telegraphic apparatus of Schilling was exhibited, at once "conceived the idea." In his "Statement of facts to the Arbitrators" in December, 1840, Mr. Cooke declares: "Mr. Möncke's experiment was at that time the only one upon the subject that I had seen or heard of. It showed that electric currents being conveyed by wires to a distance, could be there caused to

* *Phil. Trans. Roy. Soc.* 1836, vol. cxxvi, p. 107. In the "gravity battery" of Callaud, and of Varley, the porous diaphragm is dispensed with by placing the lighter liquid (a diluted solution of zinc sulphate) above the heavier liquid (a saturated solution of copper sulphate): the separation being maintained by their difference of specific gravity. In this arrangement the copper plate rests at the bottom of the cell, and the zinc plate is supported at its top.

† *Philosoph. Transac. of Roy. Soc.* (read June 19, 1834), vol. cxxiv, pp. 583–589. In this paper, Wheatstone says, that his first ineffectual attempt to discover a velocity of electricity was made in 1830. "The method by which I then proposed to effect this purpose, was announced in a lecture delivered by Dr. Faraday, at the Royal Institution, in June, 1830." (p. 583.)

deflect magnetic needles, and thereby to give signals. It was in a word a hint at the application of electricity to telegraphic purposes; but nothing more, for it provided no means of applying that power to practical uses. [!] . . . Within three weeks after the day on which I saw the experiment, I had made (partly at Heidelberg and partly at Frankfort) my first electric telegraph of the galvanometer form."* This apparatus comprised three indicating needles in connection with three circuits of six wires; each terminus of the line being provided with both transmitting keys, and indicating galvanometers. Mr. Cooke also applied a call-alarm, differing from Schilling's in having an ordinary clock-alarm, (similar to that used by Weber several years previously,) checked by an armature detent which was released on the excitement of an electro-magnet by the current. Not being skilled in electrical science however, nor aware of Henry's researches, he soon found the difficulty of operating with a "quantity" battery his galvanometer coils through a long circuit: and in February, 1837, he was introduced to Professor Wheatstone by Dr. P. M. Roget.† On comparing their respective projects of a needle telegraph, the two concluded to combine their exertions in a partnership; and in a little more than three months they secured a joint patent on their perfected system.‡ An experimental line between Euston Square and Camden Town Stations (a distance of a mile and a quarter), was worked with partial success July 25, 1837; and early in 1838, the patentees established a telegraph line between Paddington and West Dayton; the distance between these two points being about thirteen miles. Neither of these "co-inventors" appears at this time to have been aware of the early needle telegraph of Baron Schilling, whose arrangement had been so closely imitated by Mr. Cooke, and whose later simplification and improvement he had failed to reach.

As illustrative of the mistaken and inaccurate manner in which important accounts are often transmitted by even intelligent and honest men,—without due investigation and information, a quotation may here be made from the "Award" of arbitration between the subsequent conflicting claims of Cooke and of Wheatstone, rendered 27th April, 1841, by the referees, Marc Isambord Brunel, the eminent engineer, and John Frederick Daniell, the eminent chemist, meteorologist, and electrician. They state: "In March, 1836, Mr. Cooke, while engaged in scientific pursuits [!], witnessed for the first time one of those well-known experiments on electricity [!] considered as a possible means of communicating intelligence [!], which have been tried and exhibited from time to time [!] during many years by various philosophers!"§ And thus, in strange

* *The Electric Telegraph*, etc. by William Fothergill Cooke, 2 parts, 8vo. London, 1856, 1857; part ii, "Arbitration Papers," sects. 14, 18, pp. 14, 15.

† For an account of the circumstances attending and following this conference, see "Supplement," NOTE F.

‡ Messrs. Cooke & Wheatstone's English patent is dated June 12, 1837, No. 7390; and their American patent, June 10, 1840, No. 1622.

§ *The Electric Telegraph*, etc. by William Fothergill Cooke, 2 parts, 8vo., London, 1856, 1857; part i, p. 14: and part ii, p. 211; also p. 265.

exaggeration of Cooke's contribution to telegraphy, not only is Schilling's fine invention (of which the arbitrators had probably never heard) entirely overlooked, but even Professor Muncke's intelligent exposition of it, (by Mr. Cooke's representation—a "well-known experiment,") is dismissed as the recurrent exhibition "by various philosophers,"—probably as familiar in London as in Heidelberg.*

1837. About the date of the Cooke and Wheatstone patent (or a month or two later in the same year), a different form of electro-magnetic telegraph was being slowly developed in the city of New York. In the autumn of the year 1835, an American artist of acknowledged merit and of liberal education, a graduate of Yale College, about forty-five years of age, was appointed professor of the arts of design in the University of the city of New York, then recently established.† Occupying rooms in the unfinished building, he commenced experimenting on an electro-magnetic recording telegraph, the idea of which had for several years been floating in his mind. An upright square frame secured to the edge of a table, was provided with a transverse strip or shelf about midway of its height, on which was arranged a small Sturgeon electro-magnet lying upon its side, with its poles directed outward from the side of the frame. Directly in front of this, a wooden pendulum suspended from the top bar of the frame and having at its middle a small iron bar acting as an armature for the magnet, was allowed a small play to and from the lower part of the frame. To the lower end of the pendulum was attached a pencil projecting downward, and made adjustable so as to bear lightly against a strip of paper supported by a roller beneath, and slowly moved along near the edge of the table by clock-work, after the manner usually employed in recording apparatus. A single cup formed the galvanic element, and the circuit involving the electro-magnet was closed and opened by means of a lever armed with a wire fork which dipped into two mercury thimbles connected respectively

* Two other projects of needle telegraph on Ampere's and Schilling's plan, belonging to the latter part of 1837, require here only a passing notice. The first, that of a Mr. Alexander, exhibited at the Society of Arts in Edinburgh, comprised thirty transmitting keys with pins beneath, which on being depressed, closed the circuit by dipping into a transverse mercury trough, and thirty galvanometer needles at the receiving station, each carrying a light paper screen, which just covered a painted letter or mark when at rest, but which by deflection, exposed the desired letter to view. By ingeniously employing but a single wire for the return path of each circuit, the inventor required but thirty-one wires. (*Mechanics' Magazine*, London, Nov. 25, 1837, No. 746, vol. xxviii, pp. 122, 123.) The second scheme, very similar to the preceding, that of a Mr. Davy, exhibited at Exeter Hall, in London, employed but eight transmitting keys, each commanding three letters by different movements, and at the receiving desk twenty-four letters on ground glass, illuminated by a lamp, each of which became visible only on the removal of a screen on the needle, placed behind the glass. An observer remarked that in the desk "there is an aperture about 16 inches long and 3 or 4 inches wide, facing the eyes, perfectly dark. On this the signals appear as luminous letters, or combinations of letters, with a neatness and rapidity almost magical." (*Mech. Mag.* Feb. 3, 1838, No. 756, vol. xxviii, pp. 295, 296.)

† This is a different institution from the University of New York State, which has mainly a supervisory function.

with the two poles of the cup battery. A series of types having on their upper face teeth or cogs varying in number, were set up as desired in the groove of a rule or composing-stick, which was caused to pass under the free end of the circuit lever; and in this way the oscillation of the said lever over the projecting teeth determined the intervals of transmission of the magnetizing current according to the combinations previously arranged in the composing-stick. The movement of the strip of paper beneath the pencil of the pendulum produced a continuous straight line so long as the pendulum remained at rest; but at each momentary attraction of its armature by the magnet, (induced by the completion of the galvanic circuit on the passage of a tooth under the circuit lever,) the play of the pendulum caused a lateral deviation of its pencil, which thus produced a transverse V-shaped interruption of the straight line.

With this arrangement of apparatus the projector was enabled to produce signals through short circuits of wire: but he soon discovered to his dismay that on interposing more than a few yards of insulated wire, the oracle was dumb. Although the remedy for this defect (first discovered and demonstrated by Henry had been for four or five years familiar to the students of science, the reading of the artist had not been in the direction of scientific literature; and he had conducted his experiments with a surprising indifference and inattention to the existing state of knowledge upon the subject. In this emergency he wisely procured the scientific assistance of a colleague, Dr. Leonard D. Gale, professor of chemistry in the same university, and the material and mechanical assistance of Mr. Alfred Vail, of the Speedwell Iron Works near Morristown, N. J.

The following is the account given by Dr. Gale of the early condition of this experimental telegraph, and of his own connecton therewith: "In the winter of 1836–'37, Samuel F. B. Morse, who as well as myself was a professor in the New York University, city of New York, came to my lecture-room, and said he had a machine in his lecture-room or studio which he wished to show me. I accompanied him to his room, and there saw resting on a table a single-pair galvanic battery, an electro-magnet, an arrangement of pencil, a paper-covered roller, pinion-wheels, levers, &c., for making letters and figures to be used for sending and receiving words and sentences through long distances. . . . At this time as Morse assured me no man had seen the machine except his brother, Sidney E. Morse. . . . Morse's machine was complete in all its parts, and operated perfectly through a circuit of some forty feet, but there was not sufficient force to send messages to a distance. At this time I was a lecturer on chemistry, and from necessity was acquainted with all kinds of galvanic batteries; and knew that a battery of one or a few cups generates a large quantity of electricity, capable of producing heat, &c., but not of projecting electricity to a great distance; and that to accomplish this a battery of many cups is

necessary. It was therefore evident to me that the one large cup-battery of Morse should be made into ten or fifteen smaller ones to make it a battery of intensity, so as to project the electric fluid. . . . Accordingly I substituted the battery of many cups for the battery of one cup. The remaining defect in the Morse machine, as first seen by me, was that the coil of wire around the poles of the electro-magnet consisted of but a few turns only, while, to give the greatest projectile power, the number of turns should be increased from tens to hundreds, as shown by Professor Henry, in his paper published in the *American Journal of Science*, 1831. . . . After substituting the battery of twenty cups for that of a single cup, we added some hundred or more turns to the coil of wire around the poles of the magnet, and sent a message through 200 feet of conductors; then through 1,000 feet; and then through ten miles of wire arranged on reels in my own lecture-room in the New York University, in the presence of friends. All these experiments were repeated with the original Morse machine, modified as I have stated, by increasing the number of battery-cups and the number of turns of wire around the magnet."*

The following account by the author himself, of his first experiments, is taken from his own deposition in the "Bain" case, in February, 1851: "In the year 1835, I was appointed a professor in the New York City University, and about the month of November of that year I occupied rooms in the university buildings. There I immediately commenced with very limited means to experiment upon my invention. My first instrument was made up of an old picture or canvas frame fastened to a table, the wheels of an old wooden clock moved by a weight to carry the paper forward, three wooden drums, upon one of which the paper was wound and passed over the other two, a wooden pendulum suspended to the top piece of the picture or stretching frame and vibrating across the paper as it passed over the center wooden drum, a pencil at the lower end of the pendulum in contact with the paper, an electro-magnet fastened to a shelf across the picture or stretching frame opposite to an armature made fast to the pendulum, a type-rule and type, for closing and breaking the circuit, resting on an endless band (composed of carpet-binding), which passed over two wooden rollers moved by a wooden crank and carried forward by points projecting from the bottom of the rule downward into the carpet-binding, a lever with a small weight on

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* *Memorial of S. F. B. Morse*, 8vo. Washington, 1875, pp. 15–17. The practical improvements introduced by Professor Gale into the arrangement devised by Professor Morse appeared to the latter so obviously mere matters of degree that he felt confident (after they were shown) that he would himself have effected them by simple trial or experimentation; and he does not appear ever to have realized that any scientific principle was involved in the difference. But had he increased separately either the number of his galvanic elements or the number of coils upon his magnet, he would equally have failed to accomplish the desired result. The chance that he would have *combined* these increments may be estimated as very low indeed, when we consider that much wiser and more scientific heads had failed entirely to attain such purpose and arrangement.

the upper side and a tooth projecting downward at one end operated on by the type, and a metallic fork, also projecting downward over two mercury cups, and a short circuit of wire embracing the helices of the electro-magnet, connected with the positive and negative poles of the battery, and terminating in the mercury cups. . . . Early in 1836, I procured forty feet of wire, and, putting it in the circuit, I found that my battery of one cup was not sufficient to work my instrument.* . . . A practical mode of communicating the impulse of one circuit to another, such as that described in my patent of 1840, was matured as early as the spring of 1837, and exhibited then to Professor Gale, my confidential friend. Up to the autumn of 1837 my telegraphic apparatus existed in so rude a form that I felt reluctance to have it seen."†

In substantial accord with Professor Morse's deposition is that of his colleague and assistant, Professor Gale, taken in a previous case, and dated April 1, 1848, in which it is added that "On Saturday, the 2nd day of September, 1837, Professor Daubeny, of the English Oxford University, being on a visit to this country, was invited with a few friends to see the operation of the telegraph in its then rude form in the cabinet of the New York City University, where it then had been put up with a circuit of 1,700 feet of copper wire stretched back and forth in that long room. This exhibition of the telegraph, although of very rude and imperfectly constructed machinery, demonstrated to all present the practicability of the invention: and it resulted in enlisting the means, the skill, and the zeal of Mr. Alfred Vail."‡

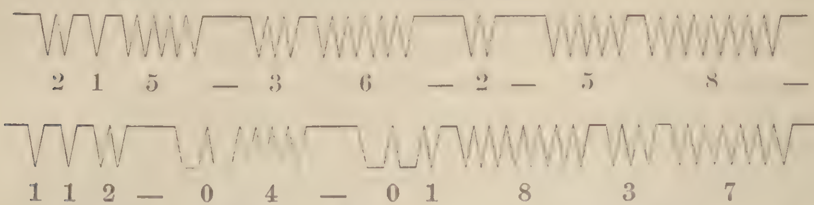
The record made on the trial exhibited September 2d, appears not to have been entirely satisfactory, for on the following Monday (September 4th) a still better performance was effected, as announced by a letter of that date addressed by Professor Morse to the editor of the New York "Journal of Commerce," in which the writer says: "I have the gratification of sending you a specimen of the writing of my telegraph, the actual transmission of a communication made this morning, in a more complete manner than on Saturday, and through the distance of one-third of a mile." This specimen of telegraphic communication, with its accompanying letter, was re produced in the "Journal of Commerce" three days

* [Had Professor Morse tried 50 or 100 cups, he would have found them equally insufficient: a fact here quite ignored.]

† *Deposition of Samuel F. B. Morse:* Feb. 6, 7, and 8, 1851. In the case of "B. B. French and others *vs.* H. J. Rogers and others." Circuit court of U. S. for E. Dist. of Pa. April session 1850. No. 104. "Complainant's Evidence." Ninth answer, pp. 167–169.

‡ *Modern Telegraphy:* a pamphlet by Professor Morse, Paris, 1867, Appendix, p. 19. This first experimental exhibition, it must be remembered, was nearly three months after the date of Cooke and Wheatstone's patent, more than a month after their successful operation through a mile and a quarter, and while the English inventors were engaged in constructing a working line from Paddington to West Dayton. Mr. A. Vail, a young man of fine abilities, was a pupil of Dr. Gale's, and was by him introduced to Professor Morse.

later, and forms the earliest publication of the actual operation of the "Morse telegraph."* The dispatch is as follows:



This cipher is thus explained by the writer, reference being had to a dictionary suitably prepared with numbered words. "To illustrate by the diagram, the word 'successful' is first found in the dictionary, and its telegraphic number, '215,' is set up in a species of type prepared for the purpose; and so of the other words. The type then operate upon the machinery and serve to regulate the times and intervals of the passage of electricity. Each passage of the fluid causes a pencil at the extremity of the wire to mark the points as in the diagram. To read the marks, count the points at the bottom of each line. It will be perceived that two points come first, separated by a short interval from the next point. Set '2' beneath it. Then comes one point, likewise separated by a short interval. Set '1' beneath it. Then come five points. Set '5' beneath them. But the next interval in this case is a *long* interval; consequently the three numbers comprise the whole number '215.' So proceed with the rest until the numbers are all set down. Then by referring to the telegraphic dictionary, the words corresponding to the numbers are found, and the communication read. Thus it will be seen that by means of the changes upon ten characters, all words can be transmitted."†

In the above line or diagram representing the telegraphic dispatch, the symbol "Λ" (or inverted V), which occurs twice in the lower line, represents a cipher or zero; and this character, when preceding a figure or group of figures, indicates that the figure or group is to be read as an actual number, and not as the index of a word. Counting thus the number of V points in the above dispatch forming groups separated by a line (—), we obtain the following numbers: "215—36—2—58—112—04—01837." And this message when translated by help of the numbered dictionary will read "Successful experiment with telegraph September 4 1837."

An account of this success, published in Silliman's Journal for October, added the statement: "Since the 4th of September, one thousand feet more of wire No. 23 have been added, making in all two thousand

* Notwithstanding the very crude condition of this invention in September, 1837, as compared with that of Schilling in 1830 (or probably in 1823), and that of Gauss in 1833, the fact that intelligible signals were actually exhibited by it at this date, fully justifies the acceptance of this period as the time of its reduction to practical operation.

† New York *Journal of Commerce*, Thursday, September 7, 1837: (on the editorial page.)

seven hundred feet, more than half a mile of a reduced size of wire. The register still recorded accurately. Arrangements have been made for constructing new and accurate machinery. Professor Gale, of the New York City University, is engaged with Professor Morse in making some interesting experiments connected with this invention, and to test the effect of length of wire on the magnetizing influence of voltaic electricity."*

Mr. Vail has given the following account of his connection with the enterprise: "On the 2d of September, 1837, the author with several others witnessed the first exhibition of this electric telegraph, and soon after became a partner with the inventor. Immediate steps were taken for constructing an instrument for the purpose of exhibiting its powers before the members of Congress. This was done at the Speedwell Iron Works, Morristown, N. J. and exhibited in operation with a circuit of two miles. A few days after, it was again exhibited at the University of the City of New York, for several days, to a large number of invited ladies and gentlemen."†

About a month after this "successful experiment," (on the 6th of October, 1837,) Professor Morse filed in the United States Patent Office a "caveat," signed October 3, stating in the petition (dated five days earlier) "that the machinery for a full practical display of his new invention is not yet completed, and he therefore prays protection of his right till he shall have matured the machinery." The specification declares: "I have invented a new method of transmitting and recording intelligence by means of electro-magnetism: . . . for the purpose aforesaid, I have invented the following apparatus, namely: First, a system of signs by which numbers, and consequently words and sentences, are signified; second, a set of type adapted to regulate and communicate the signs, with cases for convenient keeping of the type, and rules in which to set up the type; third, an apparatus called a port-rule, for regulating the movement of the type-rules, which rules by means of the type in their turn regulate the times and intervals of the passage of electricity; fourth, a register which records the signs permanently; fifth, a dictionary or vocabulary of words numbered and adapted to this system of telegraph; sixth, modes of laying the conductors to preserve them from injury." These several parts are then more particularly described. "The signs are the representatives of numerals." The register comprises an electro-magnet actuating by its armature a lever or pendulum carrying a pencil or fountain pen, or small printing wheel, for marking on a strip or sheet of paper as already described. The modes of laying the conductors are by insulating the wires with silk or cotton wrapping, and coating with caoutchouc or other non-conductor, and also by inclosing them in iron, lead, or wooden tubes. The document concludes: "What I claim as my invention, and desire to secure by letters

*Silliman's *Am. Jour. Sci.* October, 1837, vol. xxxiii, p. 187.

†A. Vail's *Electro-Magnetic Telegraph*, 8vo. 1845, p. 154.

patent and to protect for one year by a caveat, is a method of recording permanently electrical signs which by means of metallic wires or other good conductors of electricity, convey intelligence between two or more places."

Of the above described apparatus, the two most important features were those numbered the first and the fourth,—the system of signs and the recording device: and though neither of these presented much originality, the method of the former being that long established for naval signals, and the clock-moved fillet of the latter being essentially the arrangement long employed for self-registering instruments generally, yet the *combination* of these parts with the others undoubtedly possessed great practical merit; and none the less that the several elements were evidently worked out independently by the inventor. It is not a little remarkable however, that of the specified six parts of this earliest invention of Professor Morse, *not one* enters into the established "Morse telegraph" of to-day. That feature regarded by the inventor as its vital and fundamental characteristic (the fourth), the subject of his formal "claim," survived the longest; but after undergoing considerable modification, it has for more than twenty years been neglected and abandoned.

In response to a public circular which had been issued by the Secretary of the Treasury, March 10, 1837, "with a view of obtaining information in regard to the propriety of establishing a system of telegraphs for the United States," Professor Morse addressed a communication to the honorable Secretary, dated September 27, 1837, pointing out the disadvantages of the old mechanical telegraphs as being "useless the greater part of the time:" (as in foggy weather and during the night.) He then proceeded: "Having invented an entirely new mode of telegraphic communication, which so far as experiments have yet been made with it, promises results of almost marvelous character, I beg leave to present to the department a brief account of its chief characteristics." After stating that at the time when he first conceived the thought (some five years previously) he had "planned a system of signs and an apparatus to carry it into effect," he added, "although the rest of the machinery was planned, yet from the pressure of unavoidable duties I was compelled to postpone my experiments, and was not able to test the whole plan until within a few weeks. The result has realized my most sanguine expectations."

The construction of a more complete apparatus was carried on at the Speedwell Iron Works of the Messrs. Vail, near Morristown, while Professor Gale pursued his experiments at the New York City University.*

Having finished his laborious task of numbering a dictionary, October 24, 1837, Professor Morse gave more attention to the Vail Works.†

* Professor Morse, writing to Mr. Alfred Vail, October 7, 1837, says: "Professor Gale's services will be invaluable to us, and I am glad that he is disposed to enter into the matter with zeal."

† "The dictionary is at last done. You cannot conceive how much labor there has been in it, but it is accomplished; and we can now talk or write anything by numbers." Professor Morse to A. Vail, October 24, 1837. (Prime's *Life of Morse*, chap. viii, p. 326.)

On his return from a visit to the works, he wrote back to Mr. Vail, on the 13th of November, 1837, "I arrived just in time to see the experiment Professor Gale was making with the entire ten miles, and you will be gratified and agreeably surprised when I inform you that the result now is that with a little addition of wire to the coils of the small magnet which I had all along used, the power was as great apparently through ten as through three miles. This result has surprised us all (yet there is no mistake), and I conceive settles the whole matter."

In a second communication to the Secretary of the Treasury, dated November 28, 1837, Professor Morse announced this encouraging success: "I informed you that I had succeeded in marking permanently and intelligibly at the distance of half a mile. Professor Gale of our university, and Mr. Alfred Vail, of the Speedwell Iron Works, near Morristown, N. J. are now associated with me in the scientific and mechanical parts of the invention.* We have procured several miles of wire, and I am happy to announce to you that our success has thus far been complete. At a distance of five miles, with a common Cruickshanks' battery of eighty-seven plates (four by three and a half inches, each plate), the marking was as perfect on the register as in the first instance of half a mile. We have recently added five miles more (making in all ten miles) with the same result; and we now have no doubt of its effecting a similar result at any distance."

On the completion of the new receiving and recording instruments at the Speedwell Iron Works, an experimental exhibition at the place, with three miles of coated copper wire, extended around a large factory-room, was made in the presence of a few friends, on the 6th of January, 1838; and on the 11th of January another exhibition was freely opened to the public. A report of the trial in a Morristown Journal explains how "the words were put up into numbers through the dictionary; the numbers were set up in the telegraph type in about the same time ordinarily occupied in setting up the same in a printing office; they were then all passed complete by the port-rule;" and being automatically recorded at the extreme end of the wire, "the marks or numbers were easily legible, and by means of the dictionary were resolved again into words."

Shortly after this, Professor Morse (or his assistant, Mr. Vail) devised for the first time a system of *alphabetic* symbols for his telegraph. It should not be forgotten that the vertical recording-lever of the original Morse appararatus was so arranged that it must necessarily mark a *continuous* line, either straight or zig-zag. It was never devised for an "alphabet," and was incapable of an intermittent dot or dash marking. The new instrument completed by Mr. Vail, and first operated on the

* In a letter to the Hon. Francis O. J. Smith, chairman of the Committee on Commerce, House of Representatives, dated February 15, 1838, Professor Morse writes: "It is proper that I should here state that the patent-right is now jointly owned in unequal shares by myself, Professor Gale, of New York City University, and Messrs. Alfred and George Vail." The patent was not actually issued till more than two years later.

6th of January, 1838, was differently organized, the recording-lever being for the first time arranged horizontally, and having an up and down movement, with an upright magnet under one end, and the moving fillet of paper above the other.*

On the 24th of January, 1838, an exhibition of the new apparatus and of its improved operation, was given at the New York City University, in the long room of the geological cabinet, through ten miles of wire: one of the five-mile reels being placed in the outgoing portion of the circuit, and the other five-mile reel on the returning line. On this occasion for the first time the words transmitted were entered, and recorded, in the new alphabet without the aid of the numbered dictionary.† The New York Journal of Commerce in noticing this performance remarked: "Professor Morse has recently improved on his mode of marking, by which he can dispense altogether with the telegraphic dictionary, using letters instead of numbers: and he can transmit ten words per minute, which is more than double the number which can be transmitted by means of the dictionary."‡

The instrument thus brought to a satisfactory working condition, was designed to be sent to Washington for exhibition to officers of the National Government, with a view of obtaining a grant from Congress for the construction of an actual line of telegraph between two cities. On the way from New York, the apparatus with its reels of wire was exhibited at Philadelphia, before a committee of the Franklin Institute (at its hall), on the 8th of February, 1838. The committee (whose chairman was Prof. Robert M. Patterson, then Director of the United States Mint at Philadelphia), after a careful examination, reported:

"The operation of the telegraph as exhibited to us was very satisfactory. The power given to the magnet at the register through a length of wire of ten miles, was abundantly sufficient for the movements required to mark the signals. The communication of this power was instantaneous." Referring then to the probable difficulties of efficient insulation, the committee proceeded: "Mr. Morse has proposed several plans; the last being to cover the wires with cotton thread, then varnish them thickly with gum-elastic, and inclose the whole in leaden tubes. More practical and economical means will probably be devised; but the fact is not to be concealed that any effectual plan must be very expensive.§ Doubts have been raised as to the distance to which the electri-

* On the question of the origin and invention of the "Morse-Alphabet," see "Supplement," NOTE G.

† The message sent through the wire on this occasion (Wednesday, January 24, 1838,) is spoken of as "the first *sentence* that was ever recorded by the telegraph." (Prime's *Life of Morse*, 8vo. N. Y. 1875, p. 331.) It was the first employment of the rectilinear dot and dash symbols.

‡ New York *Journal of Commerce* of January 29, 1838.

§ [It is to be remembered that Gauss and Weber, as also Steinheil, at this date had in actual and successful operation telegraph lines several miles in length, whose naked wires through the air were insulated only at their points of support. Although this important discovery of Weber had been in practical and public operation for about five years, no particular account of it seems to have been at that time published in this country.]

city of an ordinary battery can be made efficient; but your committee think that no serious difficulty is anticipated as to this point. The experiment with the wire wound in a coil may not in deed be deemed conclusive. . . . It may be proper to state that the idea of using electricity for telegraphic purposes has presented itself to several individuals, and that it may be difficult to settle among them the question of originality. The celebrated Gauss has a telegraph of this kind in actual operation, for communicating signals between the University of Göttingen and his magnetic observatory in its vicinity. . . . In conclusion, the committee beg leave to state their high gratification with the exhibition of Professor Morse's telegraph, and their hope that means may be given to him to subject it to the test of an actual experiment made between stations at a considerable distance from each other." *

About the middle of February, (1838,) Professor Morse arrived in Washington with his instrument and his reels of wire, and exhibited the operation of the telegraph to many dignitaries of the executive and legislative branches of government. A memorial was presented to Congress by the inventor, asking an appropriation to defray the expense of an experimental line between two cities; which being referred to the Committee on Commerce by the House of Representatives, was favorably reported by that committee April 6, through its chairman, Hon. Francis O. J. Smith. "The committee agree unanimously that it is worthy to engross the attention and means of the Federal Government to the full extent that may be necessary to put the invention to the most decisive test that can be desirable;" and in accordance with this opinion, "the committee recommend an appropriation of thirty thousand dollars, to be expended under the direction of the Secretary of the Treasury; and to this end submit herewith a bill." This bill however failed to receive the support of the majority, and a favorable action on this measure was not obtained for several years.

Meanwhile Professor Morse had been engaged with a skillful attorney in preparing papers with a view to obtaining a patent. The specification (signed April 7, 1838) includes, in addition to the several parts described in the earlier caveat of October 3, 1837, the recently-devised system of alphabetic signs, a rotary port-rule for continuous action and a combination of circuits or electro-magnetic "relays." The invention is described as "an application of electro-magnetism in producing sounds and signs, or either, and also for recording permanently by the same means . . . any signs thus produced." "It consists of the following parts: First, a circuit of electric or galvanic conductors," etc. "Second, a system of signs by which numerals and words represented by numerals, and thereby sentences of words, as well as of numerals, and letters of any extent and combination of each, are communicated." "Third, a set of type adapted to regulate the communication of the above-mentioned signs." "Fourth, an apparatus called the port-rule [straight or

* *Journal of Franklin Institute,* February, 1838, vol. xxi, n. s. pp. 106–108.

circular] which regulates the movement of the type." "Fifth, a signal-lever which breaks and connects the circuit of conductors."* "Sixth, a register which records permanently the signs communicated." "Seventh, a dictionary, or vocabulary of words, to which are prefixed numerals." "Eighth, modes of laying the circuit of conductors."

After filing his application in the Patent Office, in order not to be forestalled in his intended efforts to obtain patents in Europe, by his own patent being sent and published abroad, Professor Morse filed a request that its issue might be suspended till his return.

Although the favorable report on the Morse memorial to Congress, made to the House of Representatives by its committee, failed to secure the appropriation recommended, Mr. Francis O. J. Smith, the chairman, was so well satisfied of the merits of the new telegraph, that on leaving Congress he at once became a partner in the enterprise, and accompanied Professor Morse in his departure for London, May 16, 1838.†

In consequence of the opposition of Wheatstone and Cooke, who had obtained an English patent June 12, 1837, Professor Morse's application for a patent in Great Britain was refused by the attorney-general, Sir John Campbell, July 12, 1838, (after the exaction of heavy fees,) on an unquestionable judicial quibble. The ostensible ground of rejection was clearly not warranted by the spirit or intent of the English patent law, as the *details* of the patent sought, had never been published either in this country or abroad.‡

The success of the American inventor in France was practically no greater; for although a nominal patent for that country was obtained on August 18, 1838, it was rendered nugatory by the ingenious legal

*Although the "signal-lever" is here specially indicated, it differs widely in construction, arrangement, and operation, from the modern signal-lever or transmitting key; having only the function in common with it of a circuit-breaker. In his pamphlet, published at Paris in 1867, giving an account of his invention, Professor Morse says: "At the time of the construction of this first telegraphic instrument, I had not conceived the idea of the present *key manipulator* dependent on the skill of the operator, but I presumed that the accuracy of the imprinting of signs could only be secured by mechanical mathematical arrangements and by automatic process." (*Modern Telegraphy*, etc. p. 25.) In his argument presented to Sir John Campbell, the attorney-general of England, July 12, 1838, he urges as an evidence of characteristic novelty, "These types form such an essential part of my invention, that without them the practical utility and value of my invention is for the most part destroyed, and full one-half of the mechanism is disconnected from it, and is of no use in it." The Morse lever must not therefore be confounded with the existing finger-key. "The spring-lever key, as at present used in the Morse office, was suggested by Mr. Thomas C. Avery, of New York, but has received various modifications." (Turnbull's *Electro-Magnetic Telegraph*, 1852, pp. 49, 50.)

†"With this understanding a partnership was formed between Professor Morse, Professor Gale, Mr. Alfred Vail, and Hon. F. O. J. Smith, by the terms of which it was stipulated that Mr. Smith should go to Europe with Professor Morse, and secure patents for the telegraph in such countries as it should be practicable for him to do so." (Prime's *Life of Morse*, chap. viii, p. 344.)

‡Notwithstanding their illiberal interference with Morse's application in 1838, Messrs. William F. Cooke and Charles Wheatstone had the "self-possession" eighteen months later each to write a letter to Professor Morse, (dated January 17, 1840,) begging him to join them in their efforts to obtain an American patent! As a characteristic illustration of official contrast, Messrs. Cooke and Wheatstone (contrary to their expectations), on their own application, secured an American patent without opposition or obstruction June 10, 1840, ten days before the issue of Morse's patent, applied for more than two years earlier.

conditions, first, that to prevent forfeiture the patented invention must be carried into successful operation in France within two years; and secondly, that all private persons, companies, or corporations, were prohibited from putting a telegraph into operation in France. Disappointed in various promising expectations, and discouraged by repeated failures, Professor Morse returned to New York, April 15, 1839.

In May, 1839, he visited Princeton, for the purpose of seeing Professor Henry and obtaining from him the solution of certain doubts;—his colleague, Dr. Gale, being then absent on business. During this his first interview with Henry, occupying an afternoon and evening, he received from the full and frank expositions of his host every satisfaction he desired; and he had the great encouragement of hearing from the lips of that cautious investigator, that he foresaw no difficulty in magnetizing soft iron through a wire "at the distance of a hundred miles or more."*

The application filed by Professor Morse in the United States Patent Office, before he visited Europe, was allowed, and issued as a patent June 20, 1840. (No. 1647.) This patent comprised nine claims: 1, the combination of type, rule, lever, &c.; 2, the recording cylinder, &c.; 3, the types, signs, &c.; 4, the making and breaking of the circuit by mechanism, &c.; 5, the combination of successive circuits; 6, the application of electro-magnets to several levers, &c.; 7, the mode and process of recording by the use of electro-magnetism; 8, the combination and arrangement of electro-magnets in one or more circuits, with armatures for transmitting signs; and 9, the combination of the mechanism described, with a dictionary of numbered words.

The appropriation asked for from Congress, though earnestly pressed at successive sessions, failed to obtain the sanction of the House of Representatives; until after a wearisome delay of five years, a bill was finally carried through Congress, March 3, 1843, authorizing an expenditure of "the sum of thirty thousand dollars, . . . for testing the capacity and usefulness of the system of electro-magnetic telegraphs invented by Samuel F. B. Morse, of New York."

The stations selected for connection by the new telegraph were Washington and Baltimore, about forty miles apart. In order to form two complete circuits for this distance, one hundred and sixty miles of copper wire, covered with cotton, were ordered and delivered at New York City. Before inclosing the four lines in pipes, as contemplated, Professor Morse prudently determined to experiment on the magnetizing effect through this continuous length of insulated wire. The result of this experiment, which fully justified the expectation of Henry expressed to him four years before, is thus stated in a letter addressed to the Secretary of the Treasury, August 10, 1843:

* Prime's *Life of Morse*, chap. x, pp. 421, 422. Dr. Prime says of this visit, "A few days after receiving Professor Henry's kind invitation, Professor Morse went to Princeton, and passing the afternoon and evening with the great philosopher, returned the next morning to New York."

"The experiments alluded to were tried on Tuesday, and with perfect success. I had prepared a galvanic battery of three hundred pairs, in order to have ample power at command; but to my great gratification, I found that one hundred pairs were sufficient to produce all the effects I desired through the whole distance of one hundred and sixty miles. It may be well to observe that the hundred and sixty miles of wire are to be divided into four lengths of forty miles each, forming a fourfold cord from Washington to Baltimore. Two wires form a circuit; the electricity therefore in producing its effects at Washington from Baltimore, passes from Baltimore to Washington and back again to Baltimore, of course travelling eighty miles to produce its result. One hundred and sixty miles therefore gives me an actual distance of eighty miles; double the distance from Washington to Baltimore. The result then of my experiments on Tuesday, is that a battery of only a hundred pairs at Washington, will operate a telegraph on my plan eighty miles distant with certainty, and without requiring any intermediate station."

As it was part of the original plan (as set forth in the caveat of 1837) to lay the conducting wires underground, Professor Morse, in 1843, devised a method of forming a lead pipe around the group of prepared and insulated wires, that is of introducing the compound cord into the pipe in the process of its construction. He obtained a patent for this project October 25, 1843, (No. 3316,) claiming "the method of introducing wires into hollow pipes whilst making the same, by introducing the wires through a hollow mandrel on which the pipe is made." This process was practically carried out, though with the extreme risk of constantly impairing the insulation of the wires by the operation.

Professor Gale has given the following account of the method of laying the telegraph line and of the result. "A plow was used, with a share running two and a half feet deep, and carrying a coil of insulated wire inclosed in a coil of lead pipe which the plow deposited in the ground and covered as the plow progressed. Forty miles of lead pipe were made in New York in the autumn of 1843, and shipped to Baltimore in the end of November. Up to this date I had been engaged in New York inspecting the manufacture of the lead pipe and charging the same with the insulated wire fed into the pipe by machinery while the pipe was drawn. I reached Baltimore in the early part of December, and learned that the party had nearly reached the Relay House. Nine miles had been laid; on inspection of which, not one mile of wire was found to be sufficiently insulated to carry the electric current from end to end of the reach."*

The plan was finally abandoned early in 1844, after more than half of

* *Morse Memorial*, Washington, 1875, pp. 18, 19. Steinheil, in 1837, remarked: "Numerous trials to insulate wires and to conduct them below the surface of the ground have led me to the conviction that such attempts can never answer at great distances, inasmuch as our most perfect insulators are at best but very bad conductors. And since in a wire of very great length the surface in contact with the so-called insulator is uncommonly large when compared with the section of the metallic conductor, there necessarily arises a gradual diminution of force." (Sturgeon's *Annals of Electricity*, etc. April, 1839, vol. iii, p. 510.)

the appropriation had been expended.* In March, 1844, it was decided to put the wires on poles, after the manner successfully adopted by Weber at Göttingen eleven years before. The different plans of insulating support proposed, were submitted by Professor Morse to Henry for his opinion, and he decided in favor of Mr. Ezra Cornell's plan of separating the wires as far apart as convenient, and attaching each wire to an independent glass insulator.† The line was accordingly erected on this plan: and by the middle or latter part of May, 1844, was completed from Washington to Baltimore. On the 24th of that month, the first formal message was transmitted through it between the two cities, and recorded by the electro-magnet in the dot-and-dash alphabet.‡ From this time the success of the electric telegraph in the United States was assured, and its extension over our broad domain was comparatively rapid.

This prolonged review of the history of the "Morse telegraph" has been ventured upon in this connection, partly to bring out into just relation and relief one or two important points, and in part to illustrate the gradual progress of development of the system, in the career of a single inventor. With that strong "subjectivity" (perhaps essential to the success both of the artist and of the artisan) which characterized him, Professor Morse always believed his invention to have been practically full-fledged at its birth, or rather at its conception; and quite unconscious of the slow and small advances derived from gathered experience or external suggestion, failed seemingly to realize how completely his earlier methods were discarded and displaced by later improvements.§

* Professor Morse says: "It was abandoned, among other reasons, in consequence of ascertaining that in the process of inserting the wire into the leaden tubes (which was at the moment of forming the tube from the lead at melting heat) the insulated covering of the wires had become charred at various and numerous points of the line to such an extent that greater delay and expense would be necessary to repair the damage than to put the wire on posts." (Prime's *Life of Morse*, chap. xi, p. 478.)

† Mr. Cornell afterward distinguished himself by devoting, in 1865, half a million of dollars from the profits of his telegraphic enterprises, to the founding at Ithaca, N. Y. of the university bearing his name. He subsequently contributed nearly as much more: making his total endowment in the neighborhood of a million dollars.

‡ The completion of the experimental telegraph authorized by act of Congress was thus formally announced by Professor Morse to the Secretary of the Treasury, under whose direction the appropriation had been placed: "Washington, June 3, 1844. SIR: I have the honor to report that the experimental essay authorized by the act of Congress on March 3, 1843, appropriating 30,000 dollars for testing my system of electro-magnetic telegraph, 'and of such length and between such points as shall test its practicability and utility,' has been made between Washington and Baltimore, a distance of forty miles, connecting the Capitol in the former city with the railroad depot in Pratt street in the latter city. . . ." This was six years after the English line of thirteen miles had been in operation. While Lemond, in 1787, and Steinheil, in 1837 had employed but a single wire for transmitting messages from either end, Morse, in 1844, required two circuits of four wires for the same performance; one pair of wires for the outward and one pair for the inward passage.

§ In a letter addressed to Donald Mann, esq., December, 1852, Professor Morse rather quaintly remarks: "In elaborating the invention in its earlier stages, many modifications of its various parts were tried, and many of the supposed improvements then deemed necessary to its perfection have since been found unnecessary and useless." (*American Telegraph Magazine*, December 15, 1852, vol. i, No. 3, p. 130.)

Morse's "first conception."—After a three years' sojourn in Europe, from 1829 to 1832, spent principally in Italy, devoted exclusively to the study and pursuit of his art as painter, Mr. Morse on his homeward voyage from France in the ship Sully, formed the acquaintance of Dr. Charles T. Jackson, of Boston, a fellow-passenger. He first "conceived the idea" of an electric telegraph on the 19th of October, 1832, from a conversation with Dr. Jackson on the subject; and the suggestion impressed him with the surprise of a truly new conception. His first thought appears to have been the application of electricity or galvanism to a chemically recording telegraph; and this project, laid aside for that of the electro-magnet, was afterward revived and cherished, till in 1849, he procured a patent for it, as already stated.

Professor Morse in his letter to Dr. C. T. Jackson, dated September 18, 1837, controverting the claim of the latter to a share in the invention of the electric telegraph, says: "I lose no time in endeavoring to disabuse your mind of an error into which it has fallen in regard to the electro-magnetic telegraph. You speak of it as 'our electric telegraph,' and as a 'mutual discovery.' . . . I have a distinct recollection of the manner, the place, and the moment, when the thought of making an electric wire the means of communicating intelligence, first came into my mind. . . . We were conversing on the recent scientific discoveries in electro-magnetism; . . . I then remarked, this being so, if the presence of electricity can be made visible in any desired part of the circuit, I see no reason why intelligence might not be transmitted instantaneously by electricity. You gave your assent that it was possible. . . . I asked you if there was not some mode of decomposition which could be turned to account. You suggested the following experiment, which we agreed should be tried together, if we could meet for that purpose. It was this: to decompose by electricity glauber salts upon the paper which was first to be colored with turmeric." The writer then argues that this plan not having been jointly tried, and an entirely different device (the electro-magnet) having been adopted by himself, there was no joint invention.*

In his letter to Dr. C. T. Jackson, dated December 7, 1837, Professor Morse says: "I consulted you to ascertain if there were not some substance easily decomposed by the simple contact of a wire in an electric state. It was then, and not till then, that you suggested turmeric paper dipped in a solution of sulphate of soda. . . . I do not charge you with intentional neglect; I readily allow your excuses for not trying the experiments; but these excuses do not alter the fact that your neglect retarded my invention, and compelled me after five years' delay, to consider the result of that experiment as a failure, and consequently to de-

* Amos Kendall's *Full Exposure of Dr. Charles T. Jackson's Pretensions*, etc. First edition, N. Y. 1850. Second edition, printed in Paris, 1867: pp. 64, 65. Neither Professor Morse nor Dr. Jackson was aware that the project had been suggested seventeen years before, by Dr. J. R. Coxe, of Philadelphia; and that it had been successfully tried four or five years before, by Mr. H. G. Dyar, of New York.

vise another mode of applying my apparatus,—a mode entirely original with me."*

In a letter to Mr. Alfred Vail, not long after having formed a partnership with that gentleman, he wrote: "I claim to be the original suggester and inventor of the electric magnetic telegraph, on the 19th of October, 1832, on board the packet-ship Sully, on my voyage from France to the United States, and consequently the inventor of the first really practicable telegraph on the electric principle."† Some ten years later he wrote to Professor Walker: "It is at the date, 1832, of Baron Schilling's invention of his needle-telegraph (since abandoned as impracticable from various and obvious causes), that I conceived my electro-magnetic telegraph, and first devised an apparatus applying magnetism produced by electricity or the power of the electro-magnet to imprint characters at a distance."‡ And such was ever his firm conviction. Some twenty years later, he wrote at Paris: "If it be asked why I have assumed the date of the year 1832 as a standpoint, I reply, because at that date the idea was first conceived, and the process and means first developed."§

The invention however as unfolded in his caveat of October 3, 1837 is sufficiently embryonic for physiological study; and though our patent law, on grounds of sound policy, excludes all evidence of the inception of a foreign competitive invention, admitting only perfected and fully published details successfully to interfere (in a question of priority) with the first suggestions of the American inventor,‖ obviously no such patriotic rule is admissible in any scientific history of the progress of actual discovery. Interesting as the earliest gleams of a successful application and invention undoubtedly are, they are too little accessible to impartial investigation to claim the prerogative of a recognized chronology.

* This letter seems very positively to exclude the claim to having "conceived the idea" of the *magnetic* telegraph in 1832.

† Vail's *Electro-Magnetic Telegraph*, 1845, p. 154.

‡ Morse's letter to Professor Sears C. Walker, dated Washington, January 31, 1848. The writer is excusable for assuming 1832 as the date of Baron Schilling's invention, (the date of his return from China,) as this is the date usually assigned in the popular text-books. Schilling's invention however so far from being either "impracticable" or "abandoned," is the essential basis of the telegraph now in use throughout England.

§ *Modern Telegraphy*, a pamphlet by S. F. B. Morse. Paris, 1867, p. 10. In a letter to Donald Mann, esq. (editor of the Telegraph Magazine), dated "Poughkeepsie, December, 1852," Professor Morse stoutly maintained his claim to priority of practical development (if not of first conception) of an electric recording telegraph; and with paternal exaggeration he declared, of his first crude experiment at the close of the year 1835, "The truth is, the child was born, and breathed, and spoke, in 1835. It had then all the essential characteristics of the future man." (*American Telegraph Magazine*, December 15, 1852, vol. i, No. 3, p. 130.) Its first transmission of an intelligible message was made September 2, 1837.

‖ "Whenever it appears that a patentee at the time of making his application for the patent believed himself to be the original and first inventor or discoverer of the thing patented, the same shall not be held to be void on account of the invention or discovery, or any part thereof, having been known or used in a foreign country before his invention or discovery thereof, if it had not been patented or described in a printed publication." (*Act of July* 4, 1836, section 15, *Revised Statutes*, approved March 2, 1877, title lx, sec. 4923.)

Whether judged by the standard of original conception, of practical operation, or of actual introduction into use, the Morse telegraph must be assigned a position tolerably low down in the list.* More than sixteen years before Professor Morse's first conception of the idea, Dr. J. R. Coxe, professor of chemistry in the University of Pennsylvania, at the beginning of 1816, "conceived the idea" of a practical electro-chemical telegraph, whose signals should be permanently *recorded* by the decomposition of metallic salts;† the precursor of Dyar's electro-chemical telegraph, successfully operated in 1828, (about five years before Morse's first conception,)—of Bain's electro-chemical telegraph, (patented December 12, 1846,)—and of Morse's electro-chemical telegraph, (patented May 1, 1849,) a third of a century afterward. Schilling's electro-magnetic telegraph developed to a "practical operation" in 1823, certainly before 1825, preceded that of Morse more than a dozen years. And the electro-magnetic telegraph of Gauss and Weber (certainly "conceived" before 1832) was in actual use and employment more than ten years before the similar establishment by Professor Morse; while that of Steinheil, probably conceived as early, was some eight years earlier than his in its practical introduction into use.‡

That Professor Morse would greatly have expedited his own improvements, and have saved himself a large amount of wasted time and labor, if he had studied more carefully the state of the art at the commencement of his experiments in 1835, is sufficiently obvious. But his complete unconsciousness—not only of the earlier successes of others in developing the galvanic telegraph, but of even the elementary facts of scientific history bearing on the problem, as well at the time of his original "conception" on board the ship Sully from the fecundating suggestion of Dr. Jackson, as during the years following, in which the invention was being slowly matured,—would be incredible on any other testimony than his own. In his first letter to the Secretary of the Treasury, dated September 27, 1837, he announced "having invented an entirely new mode of telegraphic communication." In a letter to Mr. A. Vail, some time afterward, he wrote: "I ought perhaps to say that the conception of the idea of an electric telegraph was original with me at that time, and I supposed that I was the first that had ever associated the two words together, nor was it until my invention was completed and had been successfully operated through ten miles, that I for the first time

* Nearly two years before Professor Morse had met with Dr. C. T. Jackson, Henry had "conceived" and executed an experimental electro-magnetic telegraph, of a mile circuit.

† Thomson's *Annals of Philosophy*, February, 1816, vol. vii, p. 163.

‡ In a letter to his daughter dated July 26, 1838, (written from Havre, just on his arrival in France from London,) Professor Morse says somewhat curiously of the telegraph of Wheatstone, "he has invented his I believe without knowing that I was engaged in an invention to produce a similar result; for although he dates back to 1832, yet as no publication of our thoughts was made by either, we are evidently independent of each other." (Prime's *Life of Morse*, chap. ix, p. 358.) The popular infatuation in England as to the originality and priority of the Cooke and Wheatstone telegraph is probably quite equal to that prevalent in America as to the superior claims of the Morse telegraph. Wheatstone's *scientific* distinction or his title to enduring fame, fortunately does not repose on his telegraph.

learned that the idea of an electric telegraph had been conceived by another." *

Some time earlier than this, or five years after their conversations on ship-board, Professor Morse wrote to Dr. Jackson, (in a letter dated August 27, 1837, seeking his indorsement of the writer's originality in electrical telegraphy,) and avowed: "I claim for myself, and consequently for America, priority over all other countries in the invention of a mode of communicating intelligence by electricity!" In a second letter to the same person, dated New York City University, September 18, 1837, acknowledging his correspondent's original introductory remarks on electricity and electro-magnetism during their homeward voyage, but differing from him as to some of the consequent circumstances, he affirmed: "I then remarked, this being so, if the presence of electricity can be made visible in any desired part of the circuit, I see no reason why intelligence might not be transmitted instantaneously by electricity!" And in the same letter he contended, "The *discovery* is the original suggestion of conveying intelligence by electricity.† The *invention* is devising the mode of conveying it. The discovery, so far as we alone are concerned, belongs to me: and if by an experiment which we proposed to try together we had mutually fixed upon a successful mode of conveying intelligence, then we might with some propriety be termed mutual or joint inventors. But as we have never tried any experiment together, nor has the one proposed to be tried by you, been adopted by me, I cannot see how we can be called mutual inventors. You are aware perhaps that the mode I have carried into effect after many and various experiments with the assistance of my colleague, Professor Gale, was never mentioned either by you or to you.‡ . . . . I have always said in giving any account of my telegraph, that it was on board the ship during a scientific conversation with you that I first conceived the thought of an electric telegraph. I have acknowledgments of similar kinds to make to Professor Silliman and Professor Gale, . . . and to the latter I am most of all indebted for substantial and effective aid in many of my experiments. If any one has a claim to be mutual inventor on the score of aid by hints, it is Professor Gale; but he prefers no claim of the kind." § In his third letter, dated New York City

* Vail's *Electro-Magnetic Telegraph*, p. 154.

† Professor Morse's conception of "discovery" does not appear to have been very profound.

‡ [Another explicit statement that he did not "conceive the idea" of the *magnetic* telegraph in 1832, or on board the ship Sully.]

§ Dr. Jackson in his reply, dated Boston, November 7, 1837, said: "This claim of yours is to me a matter of surprise and regret. . . . You will not I presume venture to maintain that you at that time knew anything about electro-magnetism more than what you learned from me. . . . I am certainly desirous of doing you justice to the fullest extent, and have always spoken of your merits as I hope I shall always have occasion to do. . . . Honor to whom honor is due shall be my motto, and I must I believe fail in this duty if I should say that the first idea of an electro-magnetic telegraph was conceived by an American citizen. . . . The 'discovery' is not then to be claimed by us. I have invented a new instrument; so perhaps you have, for I do not yet know what your new one is, since you say I have not seen it nor heard about it beyond your announcement."

University, December 7, 1837, Professor Morse reiterated: "Your memory and mine are at variance in regard to the first suggestion of conveying intelligence by electricity. I claim to be the one who made it, and in the way which I stated in my letter to you. . . . The idea that I had made a brilliant discovery, that it was original in my mind, was the exciting cause and the perpetual stimulus to urge me forward in maturing it to a result. Had I supposed at that time, that the thought had ever occurred to any other person, I would never have pursued it; and it was not till I had completed my present invention, that I was aware that the thought of conveying intelligence by electricity had occurred to scientific men some years before. . . . The single scientific fact ascertained by Franklin, that electricity can be made to travel any distance instantaneously, is all that I needed to know, aside from mathematical and mechanical science, in order to plan all I invented on board the ship."*

These extracts sufficiently show the distinguished inventor's profound incomprehension, as well of the nature of the problem to be solved, as of the scientific principles involved in surmounting his fundamental difficulties. That his colleague, Professor Gale, should by the mere application of existing knowledge and established fact, make his magnetic signals operative through successively increasing lengths of wire until ten miles were included in the circuit, appeared—if remarkable, at least quite natural. That any special credit should be due to any one but himself and his invention, in the accomplishment of such a result, appeared no less unnatural and irrational: and Dr. Gale has recorded "Professor Morse's great surprise" when his attention was first called to Henry's paper in Silliman's Journal of January, 1831, a year or two after his magnet and battery had been so modified in accordance therewith as to correlate them in "intensity." That even then the inventor understood the real import of the paper is rendered doubtful by subsequent developments: his surprise being apparently excited mainly by Henry's suggestion that his researches were "directly applicable to the project of forming an electro-magnetic telegraph."

Prof. Sears C. Walker, the eminent astronomer, in a deposition taken in a telegraph suit of "French *vs.* Rogers," has thus recorded his recollection of an interesting interview between Professors Henry, Morse, and Gale, in January, 1848, at which he was present: "The result of the interview was conclusive to my mind that Professor Henry was the sole discoverer of the law on which the 'intensity' magnet depends for its power of sending the galvanic current through a long circuit. I was also led to conclude that Mr. Morse in the course of his own researches and experiments, before he read Professor Henry's article before alluded to, had encountered the same difficulty Mr. Barlow and those who preceded him had encountered; that is the impossibility of forcing the galvanic

* *Full Exposure of Dr. Charles T. Jackson's Pretensions*, etc. By Amos Kendall. 1st ed. 1850; 2d ed. printed in Paris, 1867: pp. 61–74.

current through a long telegraph line. His own personal researches had not overcome this obstacle. I also learned at the same time, by the conversations above stated, that he only overcame this obstacle by constructing a magnet on the principle invented by Professor Henry, and described in his article in Silliman's Journal. His attention was directed to it by Dr. Gale."*

In consequence of this friendly interview, Professor Morse, with a frankness creditable to the natural impulses of his character, a short time afterward addressed a letter to Professor Walker, from which the following extracts are made:

"WASHINGTON, January 31, 1848.

"DEAR SIR: I have perused with much interest that part of your manuscript entitled 'Theory of Morse's Electro-Magnetic Telegraph,' which you were so kind as to submit to my examination. The allusion you make to 'the helix of a soft-iron magnet prepared after the manner first pointed out by Professor Henry,' gives me an opportunity of which I gladly avail myself, to say that I think justice has not hitherto been done to Professor Henry, either in Europe or this country, for the discovery of a scientific fact which in its bearing on telegraphs, whether of the magnetic needle or electro-magnet order, is of the greatest importance. . . . Thus was opened the way for fresh efforts in devising a practicable electric telegraph; and Baron Schilling, in 1832, and Professors Gauss and Weber, in 1833, had ample opportunity to learn of Henry's discovery, and avail themselves of it, before they constructed their needle telegraphs.† . . . To Professor Henry is unquestionably due the honor of the discovery of a fact in science which proves the practicability of exciting magnetism through a long coil or at a distance, either to deflect a needle or magnetize soft iron. . . .

"With great respect, your obedient servant,

"SAMUEL F. B. MORSE."

This just and honorable recognition was well calculated to reflect an added luster, in the minds of the intelligent, upon Professor Morse's unquestionable achievements. But the writer a few years later, perhaps embittered by the sweeping constructions placed by hostile advocates upon the enforced statements of Henry (exacted in strongly-contested litigations between rival telegraph inventors or their sustaining companies), was unfortunately led in evil hour by flattering partisans to undo this gracious work.

In a pamphlet essay dated Locust Grove, New York, December, 1853, and published in January, 1855, Professor Morse hazarded the intrepid

* *The case of French* vs. *Rogers.* Respondent's evidence, p. 199. Quoted by President Felton: *Smithsonian Report* for 1857, pp. 94, 95. The attention of Professor Morse was in reality not called to Henry's discovery by Dr. Gale, till a considerable time after it had been successfully applied to the experimental circuits of the infant telegraph.

† [Schilling's telegraphic experiments (involving no great length of circuit) were earlier than Henry's discoveries: and the expedient of so delicate an indicator as the reflecting galvanometer employed by Gauss and Weber seems to show that they had not adapted fully the electric current to the "intensity" coil, as recommended by Henry.]

statement: "First. I certainly shall show that I have not only manifested every disposition to give due credit to Professor Henry, but under the hasty impression that he deserved credit for discoveries in science bearing upon the telegraph, I did actually give him a degree of credit not only beyond what he had received at that time from the scientific world, but a degree of credit to which subsequent research has proved him not to be entitled. Secondly. I shall show that I am not indebted to him for any discovery in science bearing on the telegraph; and that all discoveries of principles having this bearing were made, not by Professor Henry, but by others, and prior to any experiments of Professor Henry in the science of electro-magnetism."*

In the inevitable dilemma thus assumed by the pamphleteer, under the clear light of historic record, it is most charitable not to impugn the writer's *candor*. The evidences diligently gathered by him, of electric impulse transmitted to great distances, before the date of Henry's investigations, certainly *seem* to show a surprising misconception of the phenomena and the principles of electro-magnetism. That with such misconception he should fail to appreciate an indebtedness to Henry's labors, is perhaps not surprising; but that he should thus ignore the services and statements of his faithful friend and colleague—Professor Gale, his great obligations to whom had been constantly admitted, appears less amenable to explanation or excuse.

Professor Morse could say with undoubted truth, that not till after the successful working of his invention, had he ever heard of Henry's researches. In his letter to Professor Walker, just above quoted, in referring to the time and the nature of his invention, he wrote: "I was utterly ignorant that the idea of an electric telegraph of any kind whatever, had been conceived by any other person. I took it for granted that the effects I desired could be produced at a distance; and accordingly in the confidence of this persuasion, I devised and constructed my apparatus for the purpose. I had never even heard or read of Professor Henry's experiments, nor did I become acquainted with them until after all my apparatus was constructed and in operation through half a mile of wire, at the New York City University, in 1837. I then learned for the first time that an electric telegraph of some kind had been thought of before I had thought of it." In his pamphlet of January, 1855, he mentions that at the date of Henry's publication in Silliman's Journal, he was sojourning in Italy. "From the autumn of the year 1829 till the autumn of the year 1832 I was in Europe, principally in Italy. . . . The fact is, it did not come to my knowledge until five years after my return, in 1837."†

* *A Defence against the injurious deductions drawn from the deposition of Prof. Joseph Henry* [in the several telegraph suits]: by Samuel F. B. Morse. January 1855, p. 8. (See "Supplement," NOTE H.)

† Morse's *Defence against the injurious deductions*, etc. (p. 15, and foot-note). Thus while Morse—dreaming only of artistic fame, was assiduously cultivating his art in Italy, nearly two years before he met with Dr. Jackson on the homeward ship, or before the conception of electric signaling had dawned upon his mind, Henry had an electro-magnetic circuit of a mile, with bell signal, in actual operation at the Albany Academy.

Professor Gale, when asked in 1856, if he would give a statement for publication, of the Morse apparatus as originally constructed, and before being modified by himself, promptly responded in a letter dated Washington, April 7, 1856: "This apparatus was Morse's original instrument, usually known as the type apparatus, in which the types, set up in a composing-stick, were run through a circuit-breaker, and in which the battery was the cylinder battery, with a single pair of plates. The sparseness of the wires in the magnet coils, and the use of the single cup battery, were to me on the first look at the instrument, obvious marks of defect, and I accordingly suggested to the professor, without giving my reasons for so doing, that a battery of many pairs should be substituted for that of a single pair, and that the coil on each arm of the magnet should be increased to many hundred turns each: which experiment (if I remember aright) was made on the same day, with a battery and wire on hand, furnished I believe by myself: and it was found that while the original arrangement would only send the electric current through a few feet of wire, (say from fifteen to forty,) the modified arrangement would send it through as many hundred. Although I gave no reasons at the time to Professor Morse for the suggestions I had proposed in modifying the arrangement of the machine, I did so afterward; and referred in my explanations to the paper of Professor Henry, in the nineteenth volume of the *American Journal of Science*. . . . At the time I gave the suggestions above named, Professor Morse was not familiar with the then existing state of the science of electro-magnetism. Had he been so, or had he read and appreciated the paper of Henry, the suggestions made by me would naturally have occurred to his mind, as they did to my own. . . . Professor Morse expressed great surprise at the contents of the paper when I showed it to him, but especially at the remarks on Dr. Barlow's results respecting telegraphing."*

In a letter published in the Sunday Chronicle at Washington, in 1872, Professor Gale (strongly vindicating the propriety of erecting a monument to Professor Morse—not as a Discoverer but as an Inventor,) conceded that "Morse knew nothing of Henry's discovery when he invented his machine. Henry's discovery was published in 1831. Five or six years later Morse invented his telegraphic machine, without having seen an account of Henry's experiments till shown to him by myself."† And from this consideration he justly exonerates him from the imputation of plagiarism which had been inconsiderately brought against the distinguished inventor. In a letter addressed to Prof. E. N. Horsford, of Cambridge, Mass., dated Washington, May 18, 1872, the same writer said: "I adapted to Morse's machine the modification which was taken from Henry's experiments of 1831. [Properly of 1829, and 1830.] But Morse, not having been accustomed to investigate scientific facts, could not appreciate the investigations of Henry as applicable to the tele-

**Smithsonian Report* for 1857, pp. 92, 93.

†*Sunday Chronicle*, Washington, March 3, 1872.

graph; and I presume that Morse never did fully appreciate the benefit which his machine derived from Henry's discovery."*

Professor Morse's real merit (and his real contribution to telegraphy) consists, first, in the adaptation of the armature of a Henry electro-magnet to the purpose of a recording instrument, and secondly, in connection therewith, the improvement on the Gauss and Steinheil dual-sign alphabets, (made either by himself, or his assistant, Mr. Vail,) of employing, instead of alternating or vibratory markings, the simple "dot-and-dash" alphabet in a single line. Whatever may have been the indebtedness of Professor Morse to Dr. Jackson for the suggestion of the first idea of an "electric" telegraph, it is quite clear from the incoherent claims of Dr. Jackson himself, that these two really important improvements were original with Morse, and were in no sense derived from Jackson.†

Claims so moderate, though so meritorious, (as might be supposed) would scarcely satisfy the ambition of the patentee and his supporters, conscious of the equally meritorious exertion and enterprise by which through tedious ordeals of obstruction and difficulty a great practical success had been achieved, and before whom—in just reward—prophetic visions of a grand commercial monopoly loomed in large perspective. And thus by ignoring and undervaluing the results accomplished by those earlier in the field, the owners of the patent exerted themselves to repress competing systems, and to arrogate entire invention and proprietorship of the electro-magnetic telegraph.

To the vast majority—suddenly dazzled by so magnificent a culmination of invention, such claims appeared entirely legitimate; to the studious few—prepared to discriminate, they appeared as entirely inadmissible. The judicial tribunals—disposed to sustain a vested right with largest and most liberal interpretation, yet pronounced in final appeal such claims untenable and overstated.‡

To so eminent a pioneer in telegraphy as Henry, perhaps more than to any other, must the overweening pretensions of the "Morse Telegraph" have been obvious and untenable; and yet with that impartiality of judgment—that rare independency of personal bias which so marvelously distinguished him, he never permitted himself to underestimate Morse's true merits, nor did he abstain from defending them with a heartiness probably greater than was accorded by any of his scientific compeers. For Professor Morse personally he felt a sympathetic regard; which continued uninterrupted and unabated till the unfortunate epoch when he was so ungratefully assailed and so wantonly traduced.§

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* *Memorial of Samuel F. B. Morse.* (Meeting in Faneuil Hall.) Boston, 1872, p. 37.

† These two features so impressed the candid Steinheil, the foremost of telegraphers, as to lead him at once to accept them as great improvements on his own ingenious method of recording, and to urge at once their substitution.

‡ See "Supplement," NOTE I. § See "Supplement," NOTE J.

"*Relay*" *and* "*receiving*" *circuits.*—The somewhat controverted question as to the true origin of the relay system of electrical communication has been purposely reserved for a concluding discussion. Though unquestionably a valuable adjunct in distant intercourse, the "relay" is not here treated as an essential feature of the electric telegraph, since land-lines of 600 miles, and by the ocean system cables of 2,000 miles, are easily made operative in a single stretch or circuit.

Henry's original contrivance of a special compound circuit in 1835, (already noticed,) by no means precluded an equally original invention by Professor Morse some years later of a different arrangement of conjoined circuits. Nor is it at all surprising that a combination (in itself sufficiently obvious) should spontaneously occur to several minds if so circumstanced as to feel a need for it. There is reason to believe that Morse, like Wheatstone, independently invented his application of the general idea, and probably about the same time, in the spring of 1837.*

To do justice however to each party, it is all-important to discriminate carefully between the actual results attained by each. Henry had simply the philosophic plan of employing a weak magnetic power to act as a distant trigger for a great magnetic power, (one therefore of short circuit,)—and there stop.† Wheatstone, employing a delicate arrangement of silent galvanometer needle at the distant station, felt the necessity of promptly calling attention to the visual signal by an audible alarm; hence this feeble power was used also as the trigger to bring into action a much shorter and more powerful electro-magnetic circuit, —but merely as a *call*, and there stop. Morse, requiring a stronger signaling duty (in the use of a recording lever) than the length of the circuit would probably permit, conceived the idea of a division of the circuit into several shorter ones; each successive circuit to be *of the same kind* as the preceding. He thus *first* produced a true "relay," and this too without a knowledge of anything similar having been previously exhibited by Professor Henry as a lecture-room experiment before his college classes. It may therefore be affirmed that Henry, feeling no occasion for *extending* a telegraphic line, had probably no idea of a "relay," properly so called, when he first devised his combination of an "intensity" circuit with a "quantity" circuit; that Professor Morse, by his own declaration, had certainly no conception of a local receiving "quantity" magnet when subsequently he first devised his combination of a series of equal "intensity" circuits; and that Wheatstone had as little idea of either a "receiving" or a "relay" magnet when (in con-

* It even appears (from the unfortunate controversy between Messrs. Cooke and Wheatstone as to the priority and value of their respective contributions) that the two English copartners each independently invented the "relay" alarum. (*Professor Wheatstone's Answer* to Mr. Cooke's pamphlet. Republished in Cooke's "*Electric Telegraph*," etc. part i, p. 55, foot-note.)

† "My object in the process described by me was to bring into operation a large 'quantity' magnet connected with a 'quantity' battery in a local circuit, by means of a small 'intensity' magnet, and an 'intensity' battery at a distance." (*Smithsonian Report* for 1857, p. 112.)

junction with Cooke) he devised a "quantity" circuit supplementary to his "intensity" circuit for the sole purpose of calling "attention."

Professor Morse in his answer to the *twelfth cross-interrogatory* (in his deposition taken February 6, 7, and 8, 1851), in the case of "B. B. French and others *vs.* H. J. Rogers and others," has made the following statement: "If by the question is sought the date of my invention of breaking and closing one circuit by another, I answer in 1836 [?]. I exhibited the same in operation [?] in the spring of 1837. If by the question is sought the date of my invention of a short circuit to be used at the extremities of the line, I answer in May of 1844. If by the question is sought the date of a still greater improvement, to wit, that of placing short circuits on the margin (so to speak) of the main line, all of them to be operated simultaneously, I answer that the idea of such an improvement first presented itself to my mind in the beginning of the year 1844.* . . . The short circuits at the extremity of the main line were first used on the line between Washington and Baltimore, in May, 1844."†

These deliberate statements of Professor Morse distinguish very explicitly between the "relay" of magnets for "breaking and closing one circuit by another," and the "receiving" magnet of "a short circuit at the extremities of the line." And as a fact of public record, Morse patented the first of these devices June 20, 1840; (No. 1647;) while he did not patent the latter device (the "receiving" magnet of a local circuit) till about six years later, April 11, 1846: (No. 4453.)

On the same subject, Professor Gale has stated in his deposition: "The said Morse always expressed his confidence of success in propagating magnetic power through any distance of electric conductors which circumstances might render desirable. His plan was thus often explained to me. Suppose (said Professor Morse) that in experimenting on twenty miles of wire we should find that the power of magnetism is so feeble that it will but move a lever with certainty but a hair's breadth; that would be insufficient it may be to write or print, yet it would be sufficient to close and break another or a second circuit twenty miles farther; and this second circuit could in the same manner be made to break and close a third circuit twenty miles farther; and so on around the globe."

This is a very clear presentation of the "relay" of circuits. But with a slight confusion of idea Dr. Gale proceeds: "This general statement of the means to be resorted to, now embraced in what is called the '*receiving magnet*,' to render practical—writing or printing by telegraph through long distances, was shown to me more in detail early in the spring of the year 1837." To the same effect, nearly a quarter of a

* [Steinheil, in 1837 (seven years earlier), had adapted his registering galvanometer "to repeat and render permanent *at all parts of the chain* where an apparatus like that above described is inserted," the information transmitted to the terminus. (Sturgeon's *Annals of Electricity*, etc. April, 1839, vol. iii, p. 520.)]

† *Deposition of Samuel F. B. Morse*, Circuit Court of the United States for the eastern district of Pennsylvania, April session, 1850, No. 104, "Complainant's Evidence," pp. 182, 183.

century later, Dr. Gale states that "Before lines of telegraph were set up, it was anticipated that in long lines the ordinary current of electricity might not be strong enough to work the magnet at such distance, so as to write, but would be so strong as to open and close a side or local circuit, as suggested by Professor Henry. This mode of using one electric circuit and magnet to open and close another electric circuit (either for extending the main circuit to greater distances or to operate any local circuit), although not in the machine when I first saw it, was *discussed* in an early part of 1837, before any lines had been constructed."*

In both these accounts, Professor Gale has inadvertently (though not unnaturally) confounded together two entirely distinct inventions, involving different arrangements and purposes:—the "relay" circuit and magnet (of the "intensity" order), and the "receiving" circuit and magnet (of the "quantity" order); although Professor Morse himself distinctly declared he had no conception of the latter arrangement in 1837, having invented it "in May of 1844."

While the first invention of the special application called the "relay" is thus unhesitatingly ascribed to Professor Morse, the practically much more important arrangement of the terminal or local short circuit "quantity" magnet for reinforcing the power of the "intensity" magnet, must as unhesitatingly be claimed for Henry; and as an invention several years prior to that of Morse, it would by the well-known principles of patent-law, have generically subordinated the special application of the latter. Although Henry did not technically "perfect the invention," it remains none the less true that every "receiving magnet" in use throughout our own and other countries is but the *obvious* application of Henry's experimental junction of the two circuits, exhibited eleven years before it entered into Professor Morse's patent of April 11, 1846.

As indicative of the relative importance of these two inventions,—the Henry "receiving" magnet and the Morse "relay" of circuits, it may be stated that on the extended lines of the "Western Union Telegraph Company," there are now 13,745 of the former in actual operation, and only 228 of the latter; being 60 of the Henry "receivers" for each of the Morse "repeaters." And in remarkable confirmation of Henry's early anticipations of the capacity of his "intensity" magnet to be operated under judicious conditions directly through a distance of several hundred miles, it is the "accomplished fact" to-day that numerous single circuits ranging from 500 to 600 miles in length, are in actual use in the United States, operated by his magnet. The telegraph-line from New York to New Orleans, (upward of 1,500 miles,) is worked in three links or circuits (connected by *two* relays or repeaters): the last circuit, from Chattanooga, Tenn. to New Orleans, La. being 638 miles long.†

* Memorial of S. F. B. Morse, Washington, 1875, p. 19. On the question of the *date* of Professor Morse's "Relay", see "Supplement," NOTE K.

† These interesting facts are communicated by the accomplished telegraphic expert, Mr Frank L. Pope (of the Western Union Telegraph Company), a vice-president of the American Electrical Society; author of "Modern Practice of the Electric Telegraph:" &c.

Among examples of "magnetic" telegraphs which might properly here receive a passing notice, are the four following:

1837. The so-called "mechanical" or chronometric telegraph of Mr. William F. Cooke, of London, comprising two synchronously revolving cylinders (or escapements) at the two stations, arrested simultaneously by a magnetic armature detent, somewhat after the general principle of Ronalds's synchronous dials of 1816, previously mentioned. This form of dial telegraph was worked by Mr. Cooke in April, 1837.*

1837. The first letter-printing telegraph, devised by Mr. Alfred Vail, of New Jersey, in September, 1837, comprising a printing-wheel provided with spring type for the letters of the alphabet, projecting radially from its periphery, and corresponding with the teeth of an escapement wheel on the same shaft or axis, driven by ordinary clock-work, and regulated by a pendulum. The pendulum oscillating as a free armature between two electro-magnets, was arrested by one of the magnets when the desired letter was reached, and another electro-magnet, with lever armature, simultaneously drew down the spring type of the letter-wheel upon the fillet of paper beneath it.† This ingenious arrangement like the dial telegraph of Ronalds, and that of Cooke (independently contrived but a short time previously), required a synchronous movement of the clocks and their pendulums at the two stations. Eighteen years later, a printing telegraph on the same principle was very successfully worked out and operated by Mr. David E. Hughes, of Kentucky.

1838. The electro-magnetic chemical telegraph of Mr. Edward Davy, of London, comprising a chemically marking or recording cylinder, operated by a clock-work escapement and the armature of an electro-magnet. Relays of circuits were also included, operated by a galvanometer needle.‡

1839. The dial telegraph of Prof. Charles Wheatstone, of London, completed by him in November, 1839, comprising an escapement and index operated by the step-motion of an electro-magnetic armature. In this arrangement, the synchronous motions and indicating positions on the terminal dials were effected entirely by the specific number of galvanic impulses given to the transmitting and receiving escapements.§ The principle of this transmission was in 1846, skillfully and successfully applied by Mr. Royal E. House, of Vermont, to a "printing telegraph."

* "Mr. Cooke's Case," before the arbitrators. *The Electric Telegraph*, etc. by W. F. Cooke, part ii, p. 23. It appears that this arrangement was devised by Mr. Cooke in 1836.

† *The American Electro-magnetic Telegraph*, by Alfred Vail, 1845, pp. 159-171.

‡ The *English patent* of Edward Davy, July 4, 1838, No. 7719.

§ "Professor Wheatstone's Case," before the arbitrators, in 1840, p. 101.

GENERAL SUMMARY.

From the foregoing partial history of the origin and development of the electro-magnetic telegraph, it is sufficiently demonstrated that its successful introduction has been effected by a considerable number of independent contributions. The leading preparatory investigations and discoveries which opened the way for the telegraph, (though with no such utilitarian end in view,) may be held to be:

1st: The discovery of galvanic electricity by Galvani (1786–1790).

2d: The galvanic or voltaic battery by Volta (1800).

3d: The directive influence of the galvanic current on a magnetic needle by Romagnosi (1802), and by Oersted (1820).

4th: The galvanometer by Schweigger (1820), the parent of the needle system.

5th: The electro-magnet by Arago and Sturgeon (1820–1825), the parent of the magnet system.

Passing these, the next most important series of steps in the evolution of our present system of telegraphy, and having a more or less conscious reference thereto, are:

First, and most vital: Henry's discovery in 1829, and 1830, of the "intensity" or spool-wound magnet, and its intimate relation to the "intensity" battery; whereby its excitation could be effected to a great distance through a very long conducting-wire.*

Second: Gauss's improvement in 1833, (or probably Schilling's improvement considerably earlier,) of reducing the electric conductors to a single circuit, by the ingenious application of a dual sign so combined as to produce a true alphabet.†

Third: Weber's discovery in 1833, that the conducting wires of an electric telegraph could be efficiently carried through the air, without any insulation except at their points of support.

Fourth: As a valuable adjunct to telegraphy, Daniell's invention of a "constant" galvanic battery in 1836.

Fifth: Steinheil's remarkable discovery in 1837, that the earth may form the returning half of a closed galvanic circuit, so that a single conducting-wire is sufficient for all telegraphic purposes.

Sixth: Morse's adaptation of the armature of a Henry electro-magnet as a recording instrument in 1837,‡ and in connection therewith the im-

*Subordinated to this important step, the use of the armature as the signaling device and the first adoption of an acoustic signal might be mentioned. If Morse's "relay" be judged by any as of sufficient importance to rank with the more essential elements, then Henry's earlier and still more important device of the terminal short circuit magnet of "quantity" must not be overlooked.

†The probable anticipations of this,—by Lomond in 1787, by Cavallo in 1795, and by Dyar in 1825,—are here neglected, as neither sufficiently definite, nor as perhaps practically influential on the progress of telegraphy: though this recurrence of idea should certainly not be lost sight of in any history of the origins of inventions.

‡September of 1837 is fixed upon as the earliest date on which an actual register of intelligible signs was made by Professor Morse. (New York *Journal of Commerce*, September 7, 1837.) These signs were not *alphabetical*, but were zig-zag markings representing numerals.

provement in 1838, on the Schilling, Gauss, and Steinheil alphabets, of employing instead of alternating signs (as in his first register), the simple "dot-and-dash" alphabet in a single line.*

As displaying the "movement of an age," it is interesting to observe that these six capital steps were all effected within the fruitful period of a single decade. If we except the first of these—the inaugurating advance, without which no electro-magnetic telegraph would have been practicable,† it will probably be difficult for the impartial historian to award to the succeeding five contributions their respective value and just desert.

The earlier needle type of the electro-magnetic telegraph, as developed by Schilling and by Gauss, has found its special and appropriate application in extended ocean-lines; and indeed without such development, it is doubtful whether we could have had a transatlantic telegraph. It is well for the exclusive partisans of the "American system" to reflect that in the operation of these submarine cables there enters no element of Morse's instrument. The receiving and indicating mechanism devised by Gauss and Weber, and introduced some ten years earlier, is essentially that in use to-day on either shore of the Atlantic Ocean. The signals of the earlier invention are equal right and left deflections of an exceedingly delicate reflecting galvanometer; the signals of the later invention are the unequal contacts of an electro-magnetic armature.

Many other telegraphic developments—not within the object of this summary, such as the various modifications of the galvanometer system, the ingenious arrangements of dial indicators, and above all—as most ingenious of all—the printing telegraphs, (originating as we have seen, with Alfred Vail,) present what may be called highly organized varieties of the art; but varieties which notwithstanding the rare order of inventive intelligence expended upon them, and the great value possessed by them in special applications, do not promise to exercise a corresponding influence upon the future of telegraphy. The wonders of multiplex telegraphy (the simultaneous transmission of two or even four or more communications in either direction over the same wire), and of vocal telegraphy (the transmutation and transmission of human speech by electric waves in the telephone), lie still more beyond the scope of this review.

In conclusion, an early averment in this historic sketch, as to "the growth of the electric telegraph," may be repeated in the language of a later writer. "The history of the subject thus far shows us that no single individual can justly claim the distinction of having been the

* Professor Morse's first use of the alphabet was made in January, 1838. (New York *Journal of Commerce*, January 29, 1838; also Prime's *Life of Morse*, 8vo, New York, 1875, p. 331.) On the subject of "Alphabetic notation" see "Supplement," NOTE L.

†Wheatstone himself does not appear to have fully realized the significance and value of Henry's researches till 1837. The simple electro-chemical telegraph might have been successfully developed without the discovery of the "intensity" magnet, and may yet prove in practice a formidable competitor with it.

inventor of the electric telegraph. It was in fact a *growth*, rather than an *invention*, the work of many brains, and of many hands." (Prescott's *Electricity and the Electric Telegraph*, 1877, chap. xxix, p. 420.)

But amid the galaxy of brilliant names who prepared the success and organized the triumph for the execution of skillful artisans, none stands higher, or shines with more resplendent luster, than that of

JOSEPH HENRY.

SUPPLEMENT.

NOTE A. (From p. 6.)

THE WORTH OF ABSTRACT RESEARCH.

The eminent natural philosopher Dr. Thomas Young, has well remarked: "No discovery however remote in its nature from the subjects of daily observation, can with reason be declared wholly inapplicable to the benefit of mankind. . . . Those who possess the genuine spirit of scientific investigation and who have tasted the pure satisfaction arising from an advancement in intellectual acquirements, are contented to proceed in their researches without inquiring at every step what they gain by their newly discovered lights, and to what practical purposes they are applicable. They receive a sufficient gratification from the enlargement of their views of the constitution of the universe, and experience in the immediate pursuit of knowledge that pleasure which others wish to obtain more circuitously by its means."*

In a similar spirit, Oersted expressed his clear perception in an anniversary address delivered in 1814, before the University of Copenhagen, that "The real laborer in science chooses *knowledge* as his highest aim. A love of knowledge, (which some are frequently obliged to place secondary to other duties,) with the man of science must be the occupation of his life; he is dedicated to nourish the holy flame of wisdom which shall diffuse its rays amidst the rest of mankind; it is his nightly lamp which shall enlighten the earth." †

And with no less earnestness and force, our own Henry declared: "While we rejoice that in our country above all others so much attention is paid to the *diffusion* of knowledge, truth compels us to say that comparatively little encouragement is given to its *increase*. . . . As soon as any branch of science can be brought to bear on the necessities, conveniences, or luxuries of life, it meets with encouragement and reward. Not so with the discovery of the incipient principles of science: the investigations which lead to these receive no fostering care from the government, and are considered by the superficial observer as trifles unworthy the attention of those who place the supreme good in that which immediately administers to the physical needs or luxuries of life. But he who loves truth for its own sake, feels that its highest claims are lowered and its moral influence marred by being continually summoned to the bar of immediate and palpable utility." ‡

In a plea for the endowment of abstract science, William Swainson, the naturalist, justly observes: "If the depths of science are to be fathomed, and new discoveries brought to light, the task can only be achieved by those whose time is at their own command, whose attention is not divided or distracted by avocations purely worldly, and whose circumstances are such as to make them free from pecuniary cares. Talents fitting their possessors for such speculations must be of a high order, and they are consequently rare: § yet still more rare it is to find superadded to them the gifts of fortune. From whom then if abstract science is to be fostered and rewarded, is

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* *Lectures on Natural Philosophy*, lect. i, vol. i, p. 2.

† *The Soul in Nature.* Bohn's Scientific Library, 1852, p. 141.

‡ *Smithsonian Report* for 1853, p. 8.

[§ Dr. Peter Mark Roget has well observed: "Important discoveries in science seem often to arise from accident; but on closer examination it is found that they always imply the exercise of profound thought. As the fertility of the soil is essential to the germination and growth of the seed which the wind may have scattered on its surface, so it is principally from the qualities of mind in the *observer* that an observation derives its value and may be made eventually to expand into an important branch of science." (*Galvanism*, 8vo, London, 1832, chap. i, p. 1.)]

this encouragement to come? Certainly not from the public; for what the multitude cannot appreciate they cannot be expected to reward. If indeed the speculations of the philosopher can be turned into immediate advantage by the manufacturer or the merchant, the inventor is in a fair way of dividing profits with the applier; but we are not at present considering such cases. . . . That discoveries which eventually have proved extensively applicable to commerce were never so suspected when their first rudiments were developed, is too notorious to be disputed; for the *discovery* and the *application* of a new principle require very different powers of mind. . . . It is a maxim of the vulgar to esteem every requirement of this sort in proportion to the direct benefit it confers on their own interests."*

It is indeed too true that the prosecution of scientific truth for truth's sake only, is popularly held in little favor, and instead of receiving assistance, is even unblushingly decried by the would-be leaders of industrial opinion. Taking no lessons from the splendid triumphs of the past, which constantly assure us that the discovery of one age—naked and unprized, is the necessary foundation for the invention of the next, intelligent editors still repeat the annual cry in superior judgment on the proceedings of learned associations, "Dispense, gentlemen, with these barren and uninteresting papers, and give us something 'practical.'"

The average citizen, professing a patronizing admiration of "science," is able perhaps to appreciate the physics of machinery, and the chemistry of manufactures. Eager for the rewards which may be won from nature by her students, he would gladly be taught some new magneto-electric process for converting cellulose into bread, or "oleomargarine" into butter; and yet in ignorant ingratitude, would as gladly monopolize the very thunderbolt, when Science once has forged it for the use of Art.†

But let those incapable of conceiving a higher utility than the material, at least exercise that prudent reason they so much vaunt, and at least endeavor to secure for that self-interest they so diligently pursue, the character of an *enlightened* policy. The unpromising preparation for a possible magnetic telegraph was quietly advanced by a fine succession of earnest students (little known or respected by the multitude), who never paused to query "the *use* of it," and who (it is safe to say) would never have accomplished their beneficent mission had their investigations been directly prompted by the inspirations of a mercenary interest.‡ It may be confidently proclaimed as a firm induction from all our past knowledge, that so intimately bound together is the entire framework and system of the world, that no extension of our observation of the phenomena of nature and of our insight into the laws of nature (which are the laws of GOD), is not either a direct advancement in physical power and well-being, or a necessary stepping-stone to other truths which shall prove such.

"Scientific researches are often supposed by the uninformed to be of little or no real importance, and indeed are frequently ridiculed as barren of all practical utility. But nothing is more mistaken than this. The most valuable and productive of the arts of life, the most important and wonder-working inventions of modern times, owe their being and value to scientific investigations. By these have been discovered physical truths and laws, the intelligent application of which to practical inventions has given immense benefits to the world. The germs of these valuable improvements and inventions have been found and developed by scientific research,—the original forms of which have often seemed to the many to be as idle and useless as they were curious." §

* Swainson, *On the Study of Natural History* (Cabinet Cyclopaedia), part iv, chap. ii, sects. 244, 245, pp. 354–357.

† "Science has scattered her material benefits so lavishly whenever she has been in presence, that no small number of her followers and all the multitude have left off gazing on the resplendency of her countenance, in their eager scramble for her gifts." (*Quarterly Review*, June, 1841, vol. lxviii, p. 185.)

‡ Of those attempting the interrogation of nature "on account of the advantage and benefit to be derived from it," it may be said in Bacon's happy simile: "Like Atalanta, they leave the course to pick up the golden apple, interrupting their speed and giving up the victory." (*Novum Organum*, book i, aphorism 70, Bohn's edition, 1858, p. 407.)

§ Report of special committee of the Board of Regents, on the distribution of the income of the Smithsonian fund. *Smithsonian Report* for 1853, p. 86.

And to the same effect let us quote in conclusion a few of Henry's urgent utterances. "Every well-established truth is an addition to the sum of human power: and though it may not find an immediate application to the economy of every-day life, we may safely commit it to the stream of time, in the confident anticipation that the world will not fail to realize its beneficial results."*

"Unfortunately there has always been in England and in this country a tendency to undervalue the advantages of profound thought, and to regard with favor only those investigations which are immediately applicable to the wants of the present hour. But it should be recollected that the scientific principles which at one period appear of no practical value, and are far removed from popular appreciation, at another time in the further development of the subject, become the means of individual prosperity and of national wealth."†

"The progress of society and the increase of the comfort and happiness of the human family depend as a basis on the degree of our knowledge of the laws by which Divine wisdom conducts the affairs of the universe. He has created us with rational souls, and endowed us with faculties to comprehend in some measure the modes in which the operations of nature are effected; and just in proportion to the advance we make by patient and persevering study in the knowledge of those modes or laws, are we enabled to apply the forces of nature to our own use and to avert the dangers to which we are exposed from our ignorance of their varied influences. Nearly all the great inventions which distinguish the present century, are the results immediately or remotely of the application of scientific principles to practical purposes; and in most cases these applications have been suggested by the student of nature, whose primary object was the discovery of abstract truth. The statement cannot be too often repeated, that each branch of knowledge is connected with every other, and that no light can be gained in regard to one which is not reflected upon all. Thus researches which at first sight appear the farthest removed from useful application, are in time found to have an important bearing on the advancement of art, and consequently on the progress of society."‡

"The world generally has failed to recognize the importance of abstract scientific truths. Although these truths constitute the most important elements of modern civilization, since they give man power and control over the inherent forces of nature, and enable him to render these the obedient slaves of his will,—yet there is even at this time, no country (however intelligent it may appear in other respects) that has made adequate provision for the discovery and development of these important principles."§

NOTE B. (From p. 16.)

THE ORIGIN OF THE GALVANOMETER.

In 1808, Johann Solomon Christian Schweigger, professor of natural philosophy at Nuremberg, and afterward at Halle, published a memoir "On the employment of the magnetic force for measuring the electrical." From the somewhat obscure description it appears however that the instrument he had devised was simply an "electroscope" for indicating the static repulsion of ordinary or mechanical electricity; the magnetic needle, armed at each end with a brass button, being mounted on an insulated stand or pivot, and used as a substitute for the torsion electrometer of Coulomb.‖ This arrangement therefore involved no principle of the galvanometer.

In 1811, De la Rive, in a letter to the editors of the "Bibliothèque Britannique." recounting some experiments, applied the term "galvanometer" to an instrument for

* *Smithsonian Report* for 1856, p. 20.

† *Agricultural Report* of Commissioner of Patents for 1857, p. 420.

‡ *Smithsonian Report* for 1859, pp. 14, 15.

§ *Smithsonian Report* for 1866, p. 16.

‖ Gehlen's *Journal für die Chemie und Physik.* 8vo, Berlin, 1808. vol. vii, pp. 205–208.

measuring the quantity of the galvanic current by its decomposing energy.* Dr. Schweigger, in a notice of this paper, remarked that he had previously measured the battery force by the quantity of gases evolved from water in a given interval. † These experiments likewise, have evidently no relation to the present use of the term "Galvanometer."

Nine years earlier than this however, (or six years before Schweigger's needle electrometer,) the galvanic deflection of the magnetic needle had been distinctly observed and accurately recorded. For more than a century, repeated endeavors had been made to discover some relation between the magnetic and the electric attractions and repulsions, or to unite them by a single law. In 1774, a prize was offered by the Academy of Bavaria for the best examination of and dissertation on the question, "Is there a real and physical analogy between electric and magnetic forces?" Professor J. H. Van Swinden, of Franeker, Holland, one of the successful competitors, supported the conclusion that the similarities were entirely superficial, and that the two powers were essentially different in kind. On the other hand, Professors Steiclehner and Hubner contended that analogies so curious must imply a single agent. ‡

But the true reaction between these agencies could not well be exhibited until after 1800, when Volta devised his galvanic battery; which for the first time enabled physicists to employ a *continuous* electric current. Gian Domenico Romagnosi, a native of Northern Italy, a celebrated publicist and author of several works on historical, legal, and political philosophy, was led near the close of the last century to occupy himself for several years with scientific investigations. The electrical problem attracted his attention, and after varied experiments with the aid of the new galvanic appliance, his versatile activity was partly rewarded; he being first of physical inquirers to make the capital discovery of the singular directive influence exerted by the galvanic current on a magnetic needle. This new phenomenon—of which he could not anticipate the importance or the consequnces, was announced in the "Gazzétta di Trento" of August 3, 1802, an Italian newspaper published at Trent, in which city he had for many years resided.§ If the channel of publication for a contribution to science of such value was unfortunate, the account was at least republished in forms better suited to arrest attention from the learned.

In a work of some note and merit, entitled "Essai Théoretique et Expérimental sur le Galvanisme," by Prof. Giovanni Aldini (a nephew of Galvani), quarto, published at Paris in 1804, the author, at page 191, alluding to the supposed magnetic influence of a galvanic circuit, states, "This new property of galvanism has been confirmed by M. Romanesi, a physicist of Trent, who has observed that galvanism produces a declination of the magnetic needle." This work was republished shortly afterward in two volumes octavo.

In the "Bibliotheque Universelle" (Sect. *Sciences et Arts*), January, 1821, (shortly after Oersted's announcement,) at page 75, attention is called to Aldini's Treatise on Galvanism, and the passage above given is quoted. The same notice and citation are also published in Gilbert's "Annalen der Physik," 1821, vol. lxviii, page 208.

* *Bibliothèque Britannique*, for February, 1811, vol. xlvi.

† "On a Galvanometer." Schweigger's *Journal für Chemie und Physik*, 8vo, Nürnberg, 1811, vol. ii, part 4, pp. 424–434.

‡ Notwithstanding the plausibility of this supposition, it remains to the present day entirely unconfirmed. The conclusion of Van Swinden was correct. The only approach to a closer analogy since obtained, is the remarkable fact discovered by Ampère in 1820, that two insulated wires, free to move, through which electricity *is flowing* in the same direction, attract each other like two dissimilar magnetic poles; and that they repel each other when their currents are reversed, like two similar magnetic poles. But the differences between these forms of attraction are still so radical, as to incline some physicists to the opinion that the one (that of magnetism) is inherent and indestructible, and the other (that of electricity) is a merely kinetic or dynamic phenomenon: while others would regard the two as both kinetic.

§ Romagnosi was chief-justice at Trent, from 1791 to 1794; and in December of 1802, not long after his scientific achievement, he was made professor of law in the University of Parma.

In a still more popular work on galvanism, by Prof. Joseph Izarn, entitled "Manuel du Galvanisme," etc. octavo, published at Paris, in 1805, in section ix, at page 120, it is also stated: "According to the observations of Romagnési, a physicist of Trent, a magnetic needle being submitted to a galvanic current undergoes a declination." This work is referred to in a discussion by Mr. Latimer Clark, of London.* Lastly, in the memoir of Romagnosi contained in the "Nouvelle Biographie Générale" (edited by Hœfer), vol. xlii, pages 574, 575, it is mentioned, "He discovered the deviation of the magnetic needle by galvanism."

Although this pregnant discovery of Romagnosi appears to have been known both to Dr. Sœmmering and to Baron Schilling in 1815, yet to neither of them did it suggest any applicability to the purpose of telegraphy. Dr. Hamel, of St. Petersburg, in his interesting account of the early history of the telegraph, informs us: "I have been endeavoring to find out from the papers of Sœmmering whether he and Baron Schilling might have had a knowledge of the Italian Gian-Domenico Romagnosi's important discovery made many years ago, that the magnetic needle deviates from its normal direction when under the influence of the galvanic current, and of which he had published an account in a newspaper at Trent on the 3d of August, 1802. . . . I found that Baron Schilling, immediately after his return to Munich in 1815, communicated to Sœmmering the little book, 'Manuel du Galvanisme,' by Joseph Izarn, professor of natural philosophy at the Lycée Bonaparte, which was printed in Paris in 1805, and in which, on page 120, mention is made of Romagnosi's discovery. I have also seen a note from Sœmmering mentioning that he had read this treatise with attention. I came however to the conclusion that neither to Sœmmering nor to Baron Schilling, had any idea of a practical application of Romagnosi's observation presented itself."† Nor is this at all surprising: for the similar discovery and announcement by Oersted in 1820, would just as little have suggested any practical method of communicating intelligence to a distance. And indeed had the experiment been attempted, it would have resulted in absolute failure. It needed the keen brains and active hands of a succession of profound investigators,—of Schweigger, and Ampère, and Arago, and Sturgeon, and Henry,—to develop fully the twofold capacity of electro-magnetism.

To the natural inquiry why the very same announcement which—made at the beginning of the century—fell as it were "still-born," should when again made eighteen years later, have sprung into so exuberant and active a vitality, the answer seems to be,—first, the greater care taken by Oersted, the later husbandman, to scatter the seed broadcast over Europe;‡ and secondly, the riper condition of the intellectual soil, at the later Spring. Romagnosi's work would seem to have been prematurely attempted; while Oersted's, no more meritorious, had the good fortune to be taken up and fostered by still more scrutinizing coadjutors: and thus while the early sowing fell by the wayside or in stony places, the later sowing fell on good ground, well prepared; and there speedily followed at the hands of a diligent band of laborers an abundant and most precious harvest.

The question may possibly arise, could Oersted have probably had any intimation of Romagnosi's earlier cultivation of the same field? Considering how little the latter name is known among scientific men to-day, the question may be confidently answered in the negative. Dr. Hamel however has ventured the severe judgment: "I cannot forego stating my belief that Oersted knew of Romagnosi's discovery announced in 1802, which was eighteen years before the publication of his own observations. It was mentioned in Giovanni Aldini's (the nephew of Galvani's) book. . . . Oersted was in Paris in 1802, and 1803, and it appears from the book of Aldini, that at the time he finished it, Oersted was still in communication with him; for he

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**Journal of the Society of Arts*, April 23, 1858, vol. vi, p. 356.

†*Journal of the Society of Arts*, July 29, 1859, vol. vii, p. 605.

‡"Hans Christian Oersted, at Copenhagen, had directed the attention of the scientific world much more effectually than Romagnosi of Italy had done, to the fact that the magnetic needle deflects when a galvanic current comes near it." Dr. Hamel. (*Jour. Soc. Arts*. 1859, vol. vii, p. 606.)

says at the end (page 376), he had not been able to add the information received from Oersted, doctor of the University at Copenhagen, about the galvanic labors of scientific men in that country."*

All that is known of Oersted's simple, generous, and upright character, utterly repels any such dark suspicion: and the remarkable interval of eighteen years, which elapsed between the two dates of publication, negatives even the probability of plagiarism. It seems only wonderful that no other experimental physicist happened to hit upon the observation in all those years.†

In Sabine's treatise on the "Electric Telegraph," reference is made in a note to Izarn's "Manual of Galvanism" and to his statement of Romagnosi's early discovery:‡ and in the second edition (of its historical portion), published two years later, Sabine remarks: "The discovery of the power of a galvanic current to deflect a magnet needle, as well as to polarize an unmagnetized one, was known to and described as early as 1805 by Professor Izarn in his 'Manuel du Galvanisme.' . . . After explaining the way to prepare the apparatus, which consists in putting a freely suspended magnet needle parallel and close to a straight metallic conductor through which a galvanic current is circulating, he describes the effects in the following words: 'According to the observations of Romagnési, a physicist of Trent, a magnetic needle, being submitted to a galvanic current, undergoes a declination; and according to those of J. Mojon, a learned chemist of Genoa, unmagnetized needles acquire by this means a kind of magnetic polarity.' To Romagnési, physicist of Trent, therefore, and not as is generally believed, to Oersted, physicist of Copenhagen, (who first observed in 1820 the phenomenon of the deflection of a magnet needle by a voltaic current,) is due the credit of having made this important discovery."§

While this is undoubtedly a correct verdict, it remains none the less true that the rapid awakening of European physicists to the significance and importance of the principle of the galvanometer, was due entirely to its rediscovery and reannouncement by Professor Hans Christian Oersted in 1820.

NOTE C. (From p. 21.)

ANTICIPATIONS OF ELECTRO-MAGNETISM.

From the Treatises on Galvanism, by G. Aldini, published in 1804, and by J. Izarn, published in 1805, (previously noticed,) we learn that Giuseppi Mojon, (Joseph Moyon in the French,) a chemist of Genoa, on placing steel sewing-needles in connection with a galvanic battery observed that they became magnetic: (probably with transverse polarity.) The description is however very obscure. (Aldini, p. 191; Izarn, p. 120.)

"It deserves to be remembered," says Dr. Hamel, "that from Aldini's book it was known that the chemist Giuseppi Mojon, at Genoa, had before 1804 observed in unmagnetized needles exposed to the galvanic current, 'a sort of polarity'. Izarn repeats this also in his 'Manuel du Galvanisme;' which book was one of those that by order were to be placed in the library of every Lycée in France".‖

Still a quarter of a century earlier, in 1777, (now a century ago,) Giovanni Baptista Beccaria, a distinguished Italian natural philosopher, professor of experimental science at Turin, and author of several works on Electricity, in the course of his experiments

* *Journal of the Society of Arts*, July 29, 1859, vol. vii, p. 606.

† "The invention all admired; and each how he
To be the inventor missed;—so easy seemed
Once found, which yet unfound, most would have thought
Impossible."
(Milton's *Par. Lost*, book vi.)

‡ *The Electric Telegraph*, by Robert Sabine, 8vo, London, 1867, part i, chap. iv, sec. 29, p. 22.

§ *History of the Electric Telegraph*, 2d edition (in Weale's Rudimentary Treatises), 1869 chap. iv, sec. 27, pp. 23, 24.

‖ *Journal of the Society of Arts*, 1859, vol. vii, p. 606.

"found that a needle through which he had sent an electric shock had in consequence acquired a curious species of polarity; for instead of turning as usual to the north and south, it assumed a position at right angles to this, its two ends pointing to the east and west."* This curious phenomenon (which if properly investigated might have led to the discovery of electro-magnetism) was exhibited by the action of common frictional or mechanical electricity; galvanism not having been discovered till some time later. It was probably this same transverse polarity that was afterward observed by Mojon.

NOTE D. (From p. 30.)

HENRY'S SPOOL MAGNET IN EUROPE.

Among the physicists of Europe who repeated Henry's experiments on a similar scale, Claude S. M. Pouillet, professor of physics at the *École Polytechnique* and director of the *Conservatoire* at Paris, made in 1832, a magnet capable of sustaining 900 pounds. At the session of the *Société Philomatique* of Paris, for June 23, 1832, Pouillet gave an account of recent experiments made by him with an electro-magnet of large size, having several thousand feet of wire wound upon it. The following is the report of this communication published in the "Bulletin" of the Society for August of that year:

"M. Pouillet communicated to the Society the results of experiments which he had just made on the magnetization of round bars of iron, (bent in horseshoe form, and surrounded on the arms with iron wire of a length of several thousand feet,) by means of an electric current established in this iron wire. The magnetism thus excited in a magnet one foot in height, formed of a bar of iron two and a half inches in diameter, and wrapped with 4,000 feet of wire, is sufficiently strong to support a weight up to 900 pounds, even when the contact of the armature with the magnet is reduced to an edge: so that the magnetic force is in this case stronger than the molecular attraction.† Attending such magnetization, on a connection being made between the two extremities of the conducting wire, a spark and a strong shock are produced. In another experiment, two similar magnets similarly arranged, having been placed facing each other, and varied in distance from contact up to a separation of a foot, the magnetization of the one produced a magnetization of the other by induction; so as to effect an electric current and spark when the two extremities of the conducting wire were brought very close together. In the latter case there was felt also a vivid shock. This shock may be communicated through a platinum wire even to the distance of a hundred feet."‡

The source of this "intensity" magnet is as unmistakable as is that of the magneto-electric spark obtained by its means. Had the experimenter however divided his 4,000 feet of wire into 50 or 60 separate coils, arranging suitably his galvanic battery in "multiple arc" as a "quantity" battery, he would certainly have greatly increased the attractive force of his magnet, and rendered it comparable to Henry's Yale-College magnet in lifting-power.

Pouillet in the third edition of his *Eléments de Physique Experimentale*, published in 1837, gives a drawing of a double "intensity" magnet arranged like Henry's in a supporting frame, of which he says: "Figures 432 and 433 represent an electro-magnet

* P. M. Roget, Treatise on *Electro-magnetism*, 1832, chap. i, art. 6, p. 3. (This treatise is included in the "Library of Useful Knowledge," vol. ii.)

†[Notwithstanding the considerable range of distance through which magnetism acts, it is not probable that the aggregate magnetic tenacity of iron in any case amounts to more than a very small fraction of its cohesive tenacity.]

‡ *Seance* of 23d June, 1832. *Nouveau Bulletin des Sciences*, publié par la "Société Philomatique de Paris," livraison pour Août, 1832, p. 127. This brief notice, republished in Quetelet's *Correspondance Mathematique et Physique* de l'Observatoire de Bruxelles, 1832, liv. v, vol. vii, pp. 317, 318, is the only paper by Pouillet on the subject of magnetization by electric currents, contained in the Catalogue of the Royal Society. Presumably therefore his only contribution on the subject.

which I constructed in 1831; and which easily supports nearly one ton (more than a thousand kilogrammes) when submitted to the current of a strong battery of 24 pairs. It consists of two horse-shoes opposed to each other, formed of round bars from three to four inches (8 to 10 centimetres) in diameter, and from two to two and a half feet (60 to 80 centimetres) in total length. The two arms of each horse-shoe are enveloped with about 1,100 yards (one thousand metres) of copper wire 25 thousandths of an inch (two-thirds of a millimetre) in thickness. The same current traverses successively the 2,200 yards (two thousand metres) of wire; but the helices are so disposed as to bring their opposite poles together." And the author repeats that as soon as the current is established, the lower free magnet is attracted to the upper fixed magnet with such force as to lift "an enormous weight, often exceeding a thousand kilogrammes."*

The remark just made applies equally to this example of the Henry "intensity" magnet, that by the substitution of the multiple coil and the "quantity" battery, it should have equalled the Henry Yale-College magnet, if not his Princeton magnet.

There is however in this latter account, an evident error of date, which should be noted. The differences of detail (in every particular) between the two magnets referred to, preclude any suggestion of the latter being an inaccurately remembered account of the former. The systematic excess of the latter magnet in every element of construction and performance equally excludes the possibility of its having been devised by its author prior to his notice before the "Société Philomatique" (on the 23d of June, 1832) of his success in developing a magnetic power of 900 pounds. And the fact that Pouillet, in the *second* edition of his Elements of Experimental Physics published in 1832 ("revue, corrigée et augmentée"), makes no allusion whatever to such a magnet, may be taken as conclusive evidence that no such magnet (nor any other) was constructed by him in 1831.†

The error of statement, in his third edition of the Elements of Physics is easily explained as a simple inadvertence in trusting to memory for a precise date.‡

It may be accepted with tolerable certainty that Pouillet's later and larger magnet could not have been made earlier than the latter part of 1832. And yet this inadvertent antedating by one year (wholly unimportant though it be) has been very precisely reproduced in the fourth edition of Pouillet's Physics, published in 1844, in the fifth edition published in 1847, in the sixth edition published in 1853, in the seventh edition published in 1856, and presumably in every subsequent edition, as well as in the numerous translations of this popular work. The earliest date of publication of Pouillet's 900-pound magnet is August, 1832; of his second, or 2200-pound magnet, is 1837.

NOTE E. (From p. 32.)

HENRY'S EARLY TELEGRAPHIC EXPERIMENTS.

The following are some of the testimonials of living eye-witnesses to the operation of Henry's early electro-magnetic telegraph, during the years 1831 and 1832.

The Hon. Alexander W. Bradford, a former pupil of the Albany Academy under Henry's professorship in 1831, and who left the academy in 1832, thus recalls his academic experiences, a third of a century later: "And there was another professor, whose life has been spared, who rose with the sun to instruct his pupil eager after knowledge; who giving his heart and soul to the duties of the school, had yet time for exploring

* *Éléments de Physique Expérimentale*, etc. par M. Pouillet, third edition, 2 vols. 8vo. Paris, 1837, liv. iii, sec. iv, chap. 5, art. 277. Vol. i, p. 572.

† *Éléments de Physique Expérimentale*, etc. par M. Pouillet, second edition, 4 vols. 8vo. Paris, 1832.

‡ As if to magnify this accidental error, Dr. Lardner, in a popular text-book on the telegraph, makes the off-hand statement: "In 1830, an electro-magnet of extraordinary power was constructed under the superintendence of M. Pouillet at Paris. . . . With a current of moderate intensity the apparatus is capable of supporting a weight of *several tons*." (Lardner and Bright's *Electric Telegraph*, 12mo., London, 1867, chap. ii, sec. 39, p. 22.)

the deep paths of science; who with his wires and silk thread winding miles of insulated copper in the commencement hall of the academy, patiently toiled his way to the demonstration of the magnetic power of the galvanic battery: and years before the invention of the telegraph, proclaimed to America and to Europe the means of communication by the electric fluid. I was an eye-witness to those experiments and to their eventual demonstration and triumph. In this commemorative festival, let us not forget to honor the name of Joseph Henry." *

On the same interesting occasion Dr. Orlando Meads thus recounted Henry's early triumph: "The older students of the academy in the years 1830, 1831, and 1832, and others who witnessed his experiments, which at that time excited so much interest in this city, will remember the long coils of wire which ran circuit upon circuit for more than a mile in length around one of the upper rooms in the academy, for the purpose of illustrating the fact that a galvanic current could be transmitted through its whole length so as to excite a magnet at the farther end of the line, and thus move a steel bar which struck a bell. This in a scientific point of view, was the demonstration and accomplishment of all that was required for the magnetic telegraph. The science of the telegraph was here complete. It needed only the inventive genius of Morse to supply the admirable instrument which was to make it available for practical use. . . . All honor to the inventor; but let us not forget that the click of the telegraph which is heard from every joint of those mystic wires which now link together every city, and village, and post, and camp, and station, all over this continent, is but the echo of that little bell which first sounded in that upper room of the academy. These facts are a part of the history of the academy; and it is fitting that on an occasion like this, so important a discovery made by one of her own sons, in her service, and under her own roof, should not be passed over in silence." †

Professor James Hall (in the same year in which he was president of the American Association, at its Albany meeting) addressed a letter to Professor Henry, dated January 19, 1856, reciting the following reminiscence:

"While a student of the Rensselaer School in Troy (New York), in August, 1832, I visited Albany with a friend, having a letter of introduction to you from Professor Eaton. Our principal object was to see your electro-magnetic apparatus, of which we had heard much, and at the same time the library and collections of the Albany Institute. You showed us your laboratory in a lower story or basement of the building, and in a larger room in an upper story, some electric and galvanic apparatus, with various philosophical instruments. In this room and extending around the same, was a circuit of wire stretched along the wall, and at one termination of this in the recess of a window a bell was fixed, while the other extremity was connected with a galvanic apparatus. You showed us the manner in which the bell could be made to ring by a current of electricity transmitted through this wire: and you remarked that this method might be adopted for giving signals by the ringing of a bell at the distance of many miles from the point of its connection with the galvanic apparatus. All the circumstances attending this visit to Albany are fresh in my recollection; and during the past years while so much has been said respecting the invention of electric telegraphs, I have often had occasion to mention the exhibition of your electric telegraph in the Albany Academy in 1832." ‡

On the occasion of a visit by Henry to the Albany Institute, about two years later than the date of the above letter, Professor Hall made public reference to the same vivid recollections. At a meeting of the Albany Institute, held Januay 13, 1858, in a hall of the Albany Academy building, "Professor Hall called attention to the fact, in connection with the visit of Professor Henry, that in 1832 he had witnessed in this

* "Commemorative Address," on the celebration of the semi-centennial anniversary of the Albany Academy, June 23, 1863. *Proceedings*, etc. p. 48.

† "Historical Discourse", at semi-centennial anniversary of Albany Academy, June 23, 1863. *Proceedings*, etc. pp. 25, 26.

‡ Published in the *Smithsonian Report* for 1857, p. 96.

building illustrations by Professor Henry of his results in electro-magnetism. He saw here a wire of great length, through which Professor Henry transmitted a current of galvanic electricity, and made the current to exert its power in ringing a bell at the extremity of the wire. This was certainly the first establishment of the practicability of the magnetic telegraph."

"Professor Henry stated that he felt gratified at this public recognition of his early labors and discoveries in reference to the electric telegraph." *

Henry's primitive electro-magnetic telegraph (as already stated) was properly an *acoustic* telegraph. Morse's subsequent electro-magnetic telegraph was a *recording* telegraph, and it was this feature of automatic register which was always regarded by its inventor as the most characteristic and important element of his invention. "It was soon discovered, after the introduction of the Morse system of telegraph, that words could be read by the click of the magnet; but paper was used upon which the arbitrary alphabet of dots and lines was indented by the instruments, for all matters of business up to 1852, and by many lines even later; but at the present time there is scarcely an office of any importance in the United States where the paper is used to receive the record. Ten years ago the practice was almost invariable in the principal offices to employ an operator to read the dispatch from the long strips of paper as it came from the instrument; and a copyist who stood by his side took it down. Now the system is entirely changed. The operator reads by the click, and copies the message himself. By this means the expense is lessened nearly one-half, and the risk of errors in a far greater ratio."† To which it may be added, that the diminished duty of the armature enables a single circuit to be operated through double the distance practicable with the Morse recorder.

And thus it has come to pass that the Morse telegraph to-day, is (by reversion to a more primitive type) essentially an *acoustic telegraph*.‡ So that "the click of the telegraph heard all over this continent," is in Dr. Meads's expressive phrase, *functionally and in truth* "but the echo of that little bell which first sounded in that upper room of the Albany Academy."

NOTE F. (From p. 39.)

HENRY'S RELATION TO THE ENGLISH TELEGRAPH.

In consequence of the repeated disagreements between the English patentees, Messrs. Cooke and Wheatstone, (not long after their procurement of a joint patent in June, 1837,) as to their respective shares of originality and credit in the invention of the needle telegraph, "Articles of Agreement" were drawn up on the 16th of November, 1840, for the submission of their grounds of claim and of dissatisfaction, to the arbitrament of two referees, Marc Isambard Brunel, on the part of Mr. Cooke, and John Frederick Daniell, on the part of Mr. Wheatstone. And in December of 1840, the

* *Trans. of Albany Institute,* vol. iv, "Proceedings," p. 245.

† Prescott's *History of Electric Telegraph*, Boston, 1860, chap. v, pp. 92–93. To the same effect is the statement in his later work: "In the larger telegraph offices of the United States and Canada, the recording instrument, or register, is entirely dispensed with, and all communications are read by the sound made by the armature lever as it vibrates between the upper and lower stops." (Prescott's *Electricity and the Electric Telegraph*, New York, 1877, chap. xxx, p. 435.)

‡ Numerous patents have been granted for "sounders," having for their object the emphasizing or re-enforcement of the sound from the receiving key or armature impacts. Prescott, in his recent work, speaking of Thomson's ingenious and extremely delicate "siphon recorder," remarks: "It is somewhat curious that in the progress of telegraphic improvement, Morse's telegraph (the most valuable feature of which originally was considered to be its capacity for recording communications) should have been modified in practice into an acoustic semaphore, while Cooke's telegraph (originally a semaphore) should at length have been also modified into a recording instrument." (*Electricity and the Electric Telegraph*, chap. xxxii, p. 561.)

contestants presented to the said arbitrators the carefully prepared statements of their respective "cases."*

Mr. Cooke, in his "Statement of Facts to the Arbitrators," gave the following account of his telegraphic failure in February, 1837, which was precisely that encountered and announced by Barlow, some dozen years before: "I employed myself in trying experiments upon the electro-magnet, with a view to discover at what distance an electric current would excite the temporary magnetism required for moving the detent of the mechanism. For this purpose I adjusted above a mile of wire in the chambers of Mr. Lane, in Lincoln's Inn: *but the magnets and battery being ill proportioned,* my experiments were unsatisfactory."† The cause of failure stated, evidently represents his acquired knowledge in 1840, not that in 1837. It was the singular fatality of electro-magnetism confronting every early experimenter from Barlow downward, that whether the number of cells in the battery were increased, or whether the length of wire coiled around the magnet were extended, the effect upon the magnet in either case *rapidly diminished* after a certain short distance of circuit. Who then would think for a moment of compounding these enfeebling arrangements?

In the desperate emergency which seemed to impose an impassable barrier to his signal device, Mr. Cooke consulted successively three among the most eminent of British electricians: Professor Faraday, Dr. Roget, and Professor Wheatstone. The following is the continuation of his own account, from the "case" already quoted: "In this scientific difficulty I sought the assistance of Dr. Faraday, who advised me to increase the number of the plates of the battery proportionably to the length of the wires; an expedient which in some degree overcame the defect of the magnet.‡ I also consulted Dr. Roget upon the same scientific point. . . . Dr. Roget informed me that Professor Wheatstone had a quantity of wire at King's College, which might assist me in trying experiments upon the electro-magnet, and he advised me on that account to submit my difficulty to him." To the same effect, in his later pamphlet published in March, 1856, (more than fifteen years afterward,) he said: "This result was to be accomplished by means of an electro-magnet: and it was my inability to make the electro-magnet act at long distances which first led me to Mr. Wheatstone." §

At this point it is proper to turn to Professor Wheatstone's statement of the interview, in his own "case," as presented to the arbitrators at the same time, in December, 1840:

"I believe but am not quite sure that it was on the first of March, 1837, that Mr. Cooke introduced himself to me. He told me that he had applied to Dr. Faraday and Dr. Roget for some information relative to a subject on which he was engaged, and that they had referred him to me as having the means of answering his inquiries. . . . Relying on my former experience, I at once told Mr. Cooke that it would not and could not act as a telegraph, because sufficient attractive power could not be imparted to an electro-magnet interposed in a long circuit; and to convince him of the truth of this assertion, I invited him to King's College to see the repetition of the experiments on which my conclusion was founded. He came, and after seeing a variety of voltaic

* These documents, with the "award" rendered April 27, 1841, published immediately afterward, were some years later republished by Mr. Cooke (together with subsequent controversial pamphlets between the parties) in two octavo volumes, under the common title, "The Electric Telegraph: was it invented by Professor Wheatstone?" One volume, published in 1856, comprising the "Arbitration Papers" in full, is injudiciously designated "Part II." The other volume, published in 1857, embracing matter of a much later date, is improperly designated "Part I." This part comprises a reprint of "Mr. Cooke's First Pamphlet," published in December, 1854; of "Mr. Wheatstone's Answer," published in January, 1856; and of "Mr. Cooke's Reply," published in March, 1856.

† *The Electric Telegraph*, etc. by W. F. Cooke, part ii, sec. 46, p. 24.

‡ Faraday in his brilliant series of researches commencing in September, 1831, employed almost exclusively Henry's "quantity" magnet of numerous short coils; and hence naturally paid little attention to the feebler energies of Henry's "intensity" magnet.

§ Work above quoted, part i, pp. 198, 199.

magnets, which even with powerful batteries exhibited only slight adhesive attraction, he expressed his disappointment."*——"When I endeavored to ascertain how a bell might be more efficiently rung, the attractive power obtained by temporarily magnetizing soft iron first suggested itself to me. The experiments I made with the long circuit at King's College however led me to conclude that the attraction of a piece of iron by an electro-magnet could not be made available in circuits of very great length, and therefore I had no hopes of being able to discharge an alarum by this means."†

Not a little surprising is it that three savans so distinguished, all of them familiar in a general way with Henry's electro-magnetic researches published more than six years before, should each have failed to apprehend, or should have forgotten, the distinctly declared virtue of his "intensity" magnet.‡ Henry, in 1829, and 1830, had fully demonstrated that while with a single galvanic pair a small magnet surrounded with a long wire showed very feeble magnetism (as compared with one of short coil), with a "trough" battery of many pairs it exerted a stronger attraction after the current had passed through 1,050 feet of wire in the circuit than when the coil was directly connected with the battery. He had announced: "From these experiments it is evident that in forming the coil we may either *use one very long wire* or several shorter ones, as the circumstances may require; in the first case our galvanic combination *must consist of a number of plates*, in the second it must be formed of a single pair." And he had expressly called attention to the fact that the former arrangement "is directly applicable to the project of forming an electro-magnetic telegraph." §

Mr. Cooke continued the narrative in his "case" as follows: "On many occasions during the months of March and April, 1837, we tried experiments together upon the electro-magnet: our object being to make it act efficiently at long distances in its office of removing the detent. The result of our experiments confirmed my apprehension that I was still without the power of exciting magnetism at long distances. . . . In this difficulty we adopted the expedient of a secondary circuit, which was used for some time in connection with my alarum."‖

It is at this period that Henry made his first visit to England; and in London he formed an acquaintance with Faraday, with Roget, and with Wheatstone, with each of whom he had many pleasant and familiar interviews, and for each of whom he ever entertained a warm personal regard. He has left the following account of his communication with the professor last named:

"In February, 1837, I went to Europe; and early in April of that year, Professor Wheatstone, of London, (in the course of a visit by myself to him in King's College, London, with Professor Bache, now of the Coast Survey,) explained to us his plans of an electro-magnetic telegraph; and among other things exhibited to us his method of bringing into action a second galvanic circuit. This consisted in closing the second circuit by the deflection of a needle so placed that the two upward projecting ends of the open circuit would be united by the contact of the end of the needle when deflected; and on opening or breaking the circuit so closed, by opening the first circuit and thus interrupting the current, the needle would resume its ordinary position under the influence of the magnetism of the earth. I informed him that I had devised another method of producing effects somewhat similar. This consisted in

* ["Electro-magnets of the greatest power, even when the most energetic batteries are employed, utterly cease to act when they are connected by considerable lengths of wire with the battery." (*Introduction to the Study of Chemical Philosophy*: by Prof. John Frederick Daniell, 2d ed. 1843, chap. xvi, sec. 859, p. 576.)]

† *The Electric Telegraph*, etc. by W. F. Cooke, part ii, sects. 268, 272, and 299, pp. 86, 87, and 93.

‡ Faraday refers to Henry's magnets in his *Experimental Researches*, etc. (Nov. 24, 1831), vol. i, art. 57, p. 15; and Roget refers to them in his excellent Treatise on *Electro-Magnetism*, 8vo. London, 1832, chap. x, sec. 161, p. 55.

§ Silliman's *American Journal of Science*, January, 1831, vol. xix, p. 404.

‖ *The Electric Telegraph*, etc. by W. F. Cooke, part ii, sec. 51, p. 27.

opening the circuit of my large quantity magnet at Princeton, when loaded with many hundred pounds weight, by attracting upward a small piece of movable wire with a small intensity magnet connected with a long wire circuit. When the circuit of the large battery was thus broken by an action from a distance the weights would fall; and great mechanical effect could thus be produced, such as the ringing of church-bells at a distance of a hundred miles or more,—an illustration of which I had previously given to my class at Princeton. . . . The object of Professor Wheatstone as I understood it, in bringing into action a second circuit, was to provide a remedy for the diminution of force in a long circuit. My object in the process described by me was to bring into operation a large quantity magnet connected with a quantity battery in a local circuit, by means of a small intensity magnet and an intensity battery at a distance."*

This important historic interchange of experiments and projects between Henry and Wheatstone, possesses an interest and a significance quite beyond that present in the contemplation of the writer. To Henry, the confidence imparted was striking only from the coincidence of separate inventions in the combination or conjunction of two circuits; in his own case by the agency of an "intensity" magnet at a distance, in the other case by the agency of a galvanometer needle at a distance.† But to Wheatstone, how different must have been the impression and suggestion! From the simple account of Henry's contrasted "intensity" and "quantity" magnets; of his telegraphic experiment in 1831,—the magnetic tapping of a bell through more than a mile of fine copper wire; of his daring faith in being able to ring heavy bells by a terminal "quantity" magnet, "*at a distance of a hundred miles or more!*" with what new interest and meaning must the earlier and neglected researches of Henry have been recalled. Who could doubt that with the unsolved problem of Mr. Cooke just fresh before him, with his active and fertile mind awakened, quick to seize upon and develop a new idea, (as well illustrated in his intercourse with Mr. Cooke,) who could doubt that the presentation above recorded (in *April* of 1837,) must have been to him a new solution and a sudden revelation?

Surely some recognition of Henry's published researches was to be looked for in return for the unexpected but unquestionable benefit conferred. We search in vain for any such requital or acknowledgment. In amplifying his own "improvements" before the arbitrators, he says: "*But the most important point of all* was my application of the theory of Ohm to telegraphic circuits, which enabled me to ascertain the best proportions between the length, thickness, &c., of the multiplying coils and the other resistances in the circuit, and to determine the number and size of the elements of the battery to produce the maximum effect. With this law and its applications, *no persons who had before occupied themselves with experiments relating to Electric Telegraphs had been acquainted*"!‡ The "theory of Ohm" (announced in 1827), had avowedly no influence whatever on Wheatstone's researches—till after his interview with Henry, in April, 1837; nor was the "theory of Ohm" any more definitely applied, or any more implicitly confirmed, by the later English experimenter in 1837, than it had been by the earlier American experimenter in 1829, and 1830. And Professor Wheatstone's explicit declarations that in *March*, 1837, he found by experience that "sufficient attractive power could *not* be

* *Smithsonian Report* for 1857, pp. 111, 112. As Prof. Alexander Dallas Bache was present on the occasion above mentioned, and as he was also subsequently a Regent of the Institution, under whose direct supervision and authority the above statement of Henry was published by the board, it may be regarded as having his implicit corroboration.

† Professor Wheatstone, in his "Answer" to Mr. Cooke's Pamphlet, says: "My experiments led me to believe that the motions of a needle could be produced at distances at which no effects of electro-magnetic attraction could be obtained." (Letter of October 26, 1840; reprint, p. 114.)

‡ "Professor Wheatstone's Case." *The Electric Telegraph*, etc. by W. F. Cooke, part ii, sect. 290, p. 91.

imparted to an electro-magnet interposed *in a long circuit*,"—that "the attraction of a piece of iron by an electro-magnet could *not* be made available in circuits *of very great length*," excludes absolutely and forever, all possibility of competitive claim to a discovery admittedly "the most important point of all" in the practical development of a real *telegraph;—the discovery of the "intensity" magnet.* Undoubtedly required to institute especial experiments in order to properly proportion his magnet and battery, Wheatstone was led by self-esteem to entirely overestimate the originality of such experiments, and correspondingly to underrate the value of Henry's instructions or suggestions.

Recurring to his plan of a terminal secondary circuit Professor Wheatstone re-iterates in the same document: "Having convinced myself that it was hopeless to expect to ring an alarum by the direct action of the electric current through a circuit of great length on an electro-magnet as ordinarily constructed, I began to think whether the effect required might not be produced in an indirect manner. It occurred to me that the difficulty would be overcome if a short circuit in which the electro-magnet of the alarum and a rather powerful electro-motor should be interposed, could be completed and broken at will by some action governed by the current in the long circuit. . . . These methods of completing the secondary circuit have lost all their importance and are scarcely worth contending about, *since my discovery* that electro-magnets may be so constructed as to produce the required effects by means of the direct current, even in very long circuits."

Again returning to this fatal theme, he repeats (having resolved to "carry out his investigations alone" without the co-operation of Mr. Cooke), "After this resolution had been taken, I commenced a series of researches *on the laws of electro-magnets*, and was fortunate enough to discover the conditions (*which had not hitherto been made the subject of philosophical inquiry*) by which effects could be produced at great distances. This rendered electro-magnetic attraction *for the first time* applicable in an immediate manner to telegraphic purposes."*—Notwithstanding that Henry, in 1830, had demonstrated—and on the first of January, 1831, had confidently announced to the scientific world, that his own original "intensity" magnet with a "trough" battery, was "directly applicable to the project of forming an electro-magnetic telegraph"!

This redundant iteration of original discovery, this reticence as to any similar investigation known to have been even *attempted* by Henry, scarcely permits the charitable suggestion of "unconsciousness." That his persistent claim should have misled his colleague, Professor Daniell, into incorporating in the text of his new edition of the "Chemical Philosophy" the following laudation, is perhaps not altogether to be wondered at: "Ingenious as Professor Wheatstone's contrivances are, they would have been of no avail for telegraphic purposes without the investigation (*which he was the first to make*) of the laws of electro-magnets when acted on through great lengths of wire."† Were the name of Henry inserted in the italicised parenthesis, the proposition stated would be beyond the reach of cavil or exception. Ingenious as Professor Wheatstone's contrivances were, *they would have been of no avail* for telegraphic purposes, without the investigation (which HENRY was the first to make)—of the laws of electro-magnets when acted on through great lengths of wire.

Mr. Cooke (to whom probably even the existence of Henry was unknown) makes the very expressive comment on the above passage from the "Chemical Philosophy" of the professor at King's College: "Mr. Daniell might have added that this investi-

* "Professor Wheatstone's Case," as above cited, sect. 306, 314, and 333, pp. 94, 96, and 100.

† *Introduction to the Study of Chemical Philosophy*, second edition, 1843, chap. xvi, sect. 859, p. 576.

gation had not been commenced or thought of in *March*, 1837!"* In this pamphlet controversy which occurred between the joint-patentees some fourteen years after the memorable "award," Professor Wheatstone in his "Answer" (of January, 1855,) to Mr. Cooke's first pamphlet (of December, 1854,) somewhat more feebly re-echoes: "With this law and its applications *no persons in* ENGLAND who had before occupied themselves with experiments relating to electric telegraphs had been acquainted."†

The substance of the "award" rendered by the distinguished arbitrators April 27, 1841, in the matter of the Cooke and Wheatstone controversy, was that "Mr. Cooke *is entitled to stand alone* as the gentleman to whom this country is indebted for having practically introduced and carried out the electric telegraph as a useful undertaking, promising to be a work of national importance: and Professor Wheatstone is acknowledged as the scientific man whose profound and successful researches have already *prepared the public to receive it* as a project capable of practical application."‡ This decision—studiously non-committal as is its language, and even as interpreted by the extra-judicial letter of Professor Daniell, dated March 24, 1843, (two years subsequently,) cannot be regarded as sustaining the prominent theory of "Professor Wheatstone's Case," assuming priority of suggestion or of application of the needle telegraph, as compared with Mr. Cooke.

NOTE G. (From p. 48.)

THE AUTHORSHIP OF THE "MORSE ALPHABET."

It appears from various concurring testimonies, that the new recording instrument constructed for Professor Morse by Mr. Vail during October, November, and December, 1837, was entirely of his own design, without any suggestions from Professor Morse: and that its arrangement for discontinuous marking was specially contrived by its maker for an alphabet exclusively devised by himself; which he abstained from publicly claiming, owing to a delicate sense of obligation incurred by his contract with Professor Morse, to render him every assistance in perfecting the mechanical arrangements of the telegraph.§

That Professor Morse had no conception on the 3d of October, 1837, of the form of nstrument contemplated by Mr. Vail, is clearly shown by his autographic "caveat" of that date. And his letter to Mr. Vail, of October 24th, announcing the completion of the numbered dictionary, (in which he wrote "we can now talk or write anything by numbers,") is equally conclusive evidence that at this later date, he was still unconscious of any alphabetic improvement.

An article in the New York Sun, by its editor, Mr. Moses S. Beach, (written in 1858,) under the heading "Honor to whom honor is due," makes the statement, "We will mention a few incidents connected with Professor Morse's own experience, which we have never seen in print, and which lose none of their interest from the unassuming modesty of the parties referred to." And after alluding to the assistance furnished

* Mr. Cooke's "Reply" to Professor Wheatstone's "Answer." (*The Electric Telegraph*, etc. by W. F. Cooke, part i, p. 199.) Dr. John Locke, of Cincinnati, who was in London in the summer of 1837, on his return to this country, having informed Professor Morse of Wheatstone's telegraphic experiments, Professor Morse in a letter from New York to Alfred Vail, at Speedwell, dated October 24, 1837, thus referred to the matter: "We have just heard that Professor Wheatstone has tried an experiment with his method, *twenty miles*, with success. We have therefore nothing to fear." (Prime's *Life of Morse*, chap. viii, p. 326.) At this date Professor Gale had operated the Morse instrument through only three miles of wire in the circuit.

† *The Electric Telegraph*, etc., by W. F. Cooke, part i, p. 57.

‡ *The Electric Telegraph*, etc., by W. F. Cooke, part i, p. 16: and part ii, pp. 214 and 268.

§ By the terms of the partnership in the telegraph, Mr. Vail agreed "to devote his personal services and skill in constructing and bringing to perfection, as also in improving, the mechanical parts of said invention, ... without charge for such personal services to the other proprietors, and for their common benefit."

the inventor in his early imperfect experiments by the Messrs. Vail, the editor continues: "Alfred Vail entered into these experiments with his whole soul, and to him is Professor Morse indebted, quite as much as to his own wit, for his ultimate triumph. *He it was who invented the far-famed alphabet;* and he too was the inventor of the instrument which bears Morse's name. But whatever he did or contrived, went cheerfully to the great end. Alfred felt rewarded in seeing the gradual accomplishment of the dream."*

In an interesting article entitled "The first week of the Telegraph," written in 1869 for a New York monthly magazine, by Dr. William P. Vail, the following significant allusion to his deceased nephew, Mr. Alfred Vail, occurs: "The birth-time and the birth-place of the telegraph as a recording instrument of *intelligence*, . . . the parties who wrought the rude original plan into working order and gave it efficiency, the man *who invented the 'Morse alphabet'* (so called), and to whose ingenuity, mechanical skill, and tireless perseverance, the clock-work of the telegraph machine is largely due, . . . all this is well understood, and for the most part is written down, and the record some day in the near future must find its place in history, upon the true principle of *suum cuique*." †

It is noteworthy that neither the published statement made by the editor of the "Sun," nor that made by Mr. Vail's uncle in the "Hours at Home," (both widely circulated, and copied into other journals during Professor Morse's life-time,) was ever called in question by the celebrated telegrapher. His painful silence under the circumstances is not easily defensible.

Mr. Francis O. J. Smith, one of the partners in the original telegraph patent of Morse, (having had as capitalist and business manager, a one-fourth interest in the enterprise,) has also stated in a published letter, dated March 30, 1872, (not long before Professor Morse's death,) that the modified horizontal lever adapted "to emboss the alphabetic characters," was "neither invented nor combined in the telegraph by Professor Morse, but exclusively by our associate—Mr. Alfred Vail; although for reasons that will be satisfactory to most minds, they were never publicly credited to him, but have been claimed exclusively by Professor Morse as his own invented combination."‡

Dr. Gale, the only surviving member of the original partnership, states in a recent letter on the subject, that he does not distinctly remember whether the changed arrangement of the lever to a horizontal position in the new model constructed by Mr. Vail, was his exclusive invention or not.

In a biographical sketch of Alfred Vail by Mr. Frederick Brent Read, of Cincinnati, published in 1873, the writer states without qualification: "Alfred Vail first produced in the new instrument the first available *Morse* machine. He invented the first combination of the horizontal lever motion to actuate a pen or pencil or style, and the entirely new telegraphic alphabet of dots, spaces, and marks, which it necessitated; and he did so prior to September, 1837, the month when the old instrument passed into his hands for reconstruction. . . . The new machine was Vail's, not Morse's.

* *New York Sun*, for September 25, 1858. Republished in the *Weekly Sun*, for October 2, 1858. In a recent letter on the subject, Mr. M. S. Beach, the author of the above, states: "I was then personally acquainted with the Vails, and a not unfrequent visitor at the homestead in Morristown; besides of course having a personal acquaintance with Professor Morse, and with the telegraph managers generally. My impression is that the article was at the time approved for its exact statement—*never controverted*."

† Scribner's *Hours at Home*, September, 1869, vol. ix, pp. 435, 436. In response to an inquiry as to the evidence of Mr. A. Vail's invention of the "dot-and-dash" alphabet, Dr. W. P. Vail, the author of the above, declares in a recent letter, "It was so understood by all who were admitted to his intimacy. In a conversation with him shortly before his death, in 1859, he so assured me. I am not aware that Mr. Morse ever set up an adverse claim."

‡ A pamphlet entitled "*History Getting Right* on the invention of the American Electro-magnetic Telegraph." 1872, p. 21. It does not appear that Professor Morse ever did explicitly claim these inventions as his own.

The claim is clearly made then, that Alfred Vail in the first place invented an entirely new alphabet; secondly, he invented an entirely new machine in which was the first combination of the horizontal lever motion to actuate a pen or pencil or style, so arranged as to perform the new duties required with precision, simplicity, and rapidity: and thirdly, Vail invented, several years afterward [in 1844], the new lever and [grooved] roller which embossed into paper the wholly simple and perfect alphabetic characters which he alone originated."*

Numerous experiments with various kinds of pencils, fountain-pens, and inked roulettes, having shown their inefficiency for the uniform marking of the "dot-and-dash" alphabet, Alfred Vail at last boldly discarded all marking devices, and employed a blunt steel point near the end of the registering lever, playing directly over a narrow groove in the roller which supported the record-fillet of paper. In this manner the variable lines of the Vail alphabet were permanently indented in the paper, with perfect facility and unerring regularity. Mr. F. B. Read in his biographical sketch of Samuel F. B. Morse (in the work just quoted), after alluding to his original apparatus as being placed by him "in Mr. Vail's hands for an entire mechanical reconstruction throughout, to speak a language not only wholly unknown to the first machine, but to perform entirely new functions, and to produce an entirely new system of signs and letters which the first by its structure was physically incapable of being made to speak;" adds with regard to Mr. Vail's subsequent improvement, "His more perfect invention of a steel style upon a lever which could strike into the paper as it was drawn onward over a grooved roller and *emboss* upon it the same alphabetic characters, was not made until 1844, about the time the first line of telegraph began to operate between Baltimore and Washington."†

Simple as may appear the substitution of the dry point for the inked wheel or pen, its introduction effected a wonderful saving of time, of attention, and of annoyance. In a memorandum attached to the original model of the lever-style and grooved roller, Alfred Vail wrote, "I have not asserted publicly my right as first and sole inventor, because I wished to preserve the peaceful unity of the invention, and because I could not according to my contract with Professor Morse, have got a patent for it."‡

Mr. Read, in the same biography of Morse, after quoting his feeble and insufficient tribute to Vail, in his speech at the banquet given at New York on the evening of December 29, 1868, in honor of the "successful" inventor, (in which he said of his intellectual offspring, "It found a friend in Mr. Alfred Vail, of New Jersey, who with his father and brother *furnished the means* to give the child a decent dress;") makes the comment, "It would have been more magnanimous if in those last days of the aged savant he had stated the precise facts, and given Alfred Vail the full credit to which he was justly entitled. He would thus have generously raised a fitting monuto the memory of one who had years before 'been gathered to his fathers' in the prime of manhood, who had with wondrous modesty and singular reticence refrained from claiming as of his own invention, the improved 'Morse' instrument and alphabet."§

In again referring to this subject in his following sketch of the life of Vail, the author adds, "These are the quiet and subdued terms in which Professor Morse was content to hand his co-inventor and early friend down to posterity. He makes no allusion to Alfred Vail which would lead any one to suspect that he was anything more than a skillful mechanic;—that Vail had ever done anything beyond putting into form the conception of Morse's brain. To say the least, it was an unhappy holding off from a magnanimous and generous course."‖

*A collection of biographical notices, entitled *Up the Heights of Fame and Fortune*, by F. B. Read, 8vo. Cincinnati, 1873, pp. 270, 271. Thirty-four pages are devoted to an account of the life of Alfred Vail; who died at Morristown, January 18, 1859.

† *Up the Heights of Fame and Fortune*, pp. 244, 245.

‡ Quoted in same work: p. 291.

§ Same work: p. 244.

‖ Same work: p. 297. A friend of Mr. Vail, (unnamed,) who visited Professor Morse at his request during his last illness in March, 1872, is reported as stating, "In

At a meeting of the Directors of the "Magnetic Telegraph Company" held at Philadelphia on the 16th of February, 1859, for the purpose of giving expression to their feelings on the recent death of Alfred Vail (a brother Director), Amos Kendall in seconding and warmly supporting the offered resolutions of respect and grief, is thus reported: "In the words of the distinguished associate and friend of both, the Hon. Amos Kendall, 'If justice be done, the name of Alfred Vail will forever stand associated with that of Samuel F. B. Morse, in the history of the invention and introduction into public use, of the Electro-magnetic Telegraph. . . . Mr. Vail was one of the most honest and scrupulously conscientious men with whom it has ever been my fortune to meet.'"*

Surely it is time that Alfred Vail should receive the tardy justice of some public acknowledgment of his very ingenious and meritorious inventions in telegraphy, and of grateful remembrance particularly for his valuable contribution to the "Morse system" of its practically most important element.

NOTE H. (From p. 60.)

AN UNWARRANTED ARRAIGNMENT.

Henry, elected December 3, 1846, to the position of "Secretary" and Director of the Smithsonian Institution, was for ten years engaged in a difficult but resolute struggle to impress upon its administration his own sagacious and far-sighted policy: at that time but little appreciated by the vast majority of those who wielded political or literary influence. It was during the latter portion of this critical period, while still almost entirely abstracted from his favorite pursuits, that he was made the subject of a most wanton, unprovoked, and unlooked-for aspersion. In this ill-advised attack—elaborately prepared either by or for Professor Morse, more than a year before its wide-spread publication,† the pamphleteer not only boldly assailed the scientific reputation of the great experimental physicist, but ventured (for the first time in the latter's career) to impugn his *truthfulness*, in an important testimony given in certain telegraph suits, some half a dozen years previously, in reluctant obedience to legal summons.‡ This testimony thus exacted, of course failed to sustain the complainant's exorbitant claims to all possible forms of the electro-magnetic telegraph, and correspondingly failed to satisfy the cupidity of the actual prosecutors; and in this remarkable accusation, first published in 1855, could readily be discerned the mercenary inspiration of interested capitalists and assignees—anxious only to stretch the monopoly to its extremest grasp. To Professor Morse himself, in his early efforts, Henry had generously rendered every encouragement and assistance; and in

a conversation of two hours, he several times said, 'The one thing I want to do now, is justice to Mr. Vail.' . . . Just four weeks from that day, he passed from earth; and I have never heard that he left one word for it. Indeed, I did not expect that he would." To this statement, Mr. Read adds, "Here we leave Professor Morse and his relations to Alfred Vail. Our only purpose has been simply to bring the facts concerning this wonderful invention, to the light of day. (Same page of the work: — p. 297.)

* Same work: p. 296.

† Professor Morse's signature upon the last page of the Impeachment (p. 96), is dated December, 1853. The pamphlet was published January, 1855.

‡ The Hon. S. P. Chase, while Governor of Ohio, (subsequently Chief Justice of the Supreme Court of the United States,) in a letter to Henry, dated Columbus, November 26, 1856, after reciting his professional connection with the litigations of 1849, says: "I remember very well that you were unwilling to be involved in the controversy even as a witness, and that you only submitted to be examined in compliance with the requirements of law. Not one of your statements was volunteered; they were all called out by questions propounded either verbally or in writing. . . . You could not have refused to respond to the questions propounded without subjecting yourself to judicial animadversion and constraint. Nothing in what you testified, or your manner of testifying, suggested to me the idea that you were animated by any desire to arrogate undue merit to yourself, or to detract from the just claims of Professor Morse."

his later successes had as freely extended his congratulations and his testimonials of the practical merits of his invention.*

To descend to a personal controversy with Mr. Morse, was utterly repugnant to Henry's feelings; to permit his serious impeachment to stand untraversed, appeared scarcely less objectionable. With a calm and self-respecting dignity, Henry simply presented the published arraignment to the Board of Regents, for their consideration and action, with a communication dated March 16, 1857, in the following terms:

"GENTLEMEN: In the discharge of the important and responsible duties which devolve upon me as Secretary of the Smithsonian Institution, I have found myself exposed, like other men in public positions, to unprovoked attack and injurious misrepresentation. Many instances of this it may be remembered occurred about two years ago, during the discussions relative to the organic policy of the Institution; but though very unjust, they were suffered to pass unnoticed, and generally made I presume no lasting impression on the public mind. During the same controversy however there was one attack made upon me of such a nature, so elaborately prepared and widely circulated by my opponents, that though I have not yet publicly noticed it, I have from the first thought it my duty not to allow it to go unanswered. I allude to an article from the pen of Prof. S. F. B. Morse, the celebrated inventor of the American electro-magnetic telegraph. In this, not my scientific reputation merely, but my moral character was pointedly assailed; indeed, nothing less was attempted than to prove that in the testimony which I had given in a case where I was at most but a reluctant witness, I had consciously and willfully deviated from the truth, and this too from unworthy and dishonorable motives.

"Such a charge, coming from such a quarter, appeared to me then, as it appears now, of too grave a character and too serious a consequence to be withheld from the notice of the Board of Regents. I therefore presented the matter unofficially to the Chancellor of the Institution, Chief Justice Taney, and was advised by him to allow the matter to rest until the then existing excitement with respect to the organization of the Institution should subside: . . . and I now embrace the first opportunity of bringing the subject officially to your notice, and asking from you an investigation into the justice of the charges alleged against me. And this I do most earnestly, with the desire that when we shall all have passed from this stage of being, no imputation of having attempted to evade in silence so grave a charge shall rest on *me*,—nor on *you*, of having continued to devolve upon me duties of the highest responsibility, after that was known to some of you individually, which if true should render me entirely unworthy of your confidence. Duty to the Board of Regents, as well as regard to my own memory, to my family, and to the truth of history, demands that I should lay this matter before you, and place in your hands the documents necessary to establish the veracity of my testimony so falsely impeached, and the integrity of my motives so wantonly assailed."†

A select committee of the Board of Regents having accordingly been appointed to examine fully into the imputations referred to, and thereupon to report the conclusion reached,—after a careful consideration of all the evidence and documents accessible, presented through its chairman, President Felton, of Harvard University, a comprehensive report, from which the following extracts are made:

"The committee have carefully examined the documents relating to the subject, and especially the article to which the communication of Professor Henry refers. This article occupies over ninety pages, and purports to be 'a defense against the injurious

* "It was my wish in every statement to render Mr. Morse full and scrupulous justice. While I was constrained therefore to state that he had made no discoveries in science, I distinctly declared that he was entitled to the merit of combining and applying the discoveries of others in the invention of the best practical form of the magnetic telegraph. My testimony tended to establish the fact that though not entitled to the exclusive use of the electro-magnet for telegraphic purposes, he was entitled to his particular machine, register, alphabet, &c. This however did not meet the full requirements of Mr. Morse's comprehensive claim."

† *Smithsonian Report* for 1857, pp. 85, 86.

reductions drawn from the deposition of Prof. Joseph Henry (in the several telegraph suits), with a critical review of said deposition, and an examination of Professor Henry's alleged discoveries bearing upon the electro-magnetic telegraph.' The first thing which strikes the reader of this article is, that its title is a misnomer. It is simply an assault upon Professor Henry; an attempt to disparage his character; to deprive him of his honors as a scientific discoverer; to impeach his credibility as a witness, and his integrity as a man. It is a disingenuous piece of sophistical argument, such as an unscrupulous advocate might employ to pervert the truth, misrepresent the facts, and misinterpret the language in which the facts belonging to the other side of the case are stated.

"Mr. Morse charges that the deposition of Professor Henry 'contains imputations against his (Morse's) personal character,' which it does not, and assumes it as a duty 'to expose the utter non-reliability of Professor Henry's testimony;' that testimony being supported by the most competent authorities, and by the history of scientific discovery. He asserts that he 'is not indebted to him [Professor Henry] for any discovery in science bearing on the telegraph,' he having himself acknowledged such indebtedness in the most unequivocal manner, and the fact being independently substantiated by the testimony of Sears C. Walker, and the statement of Mr. Morse's own associate, Dr. L. D. Gale. Mr. Morse further maintains that all discoveries bearing upon the telegraph were made not by Professor Henry, but by others, and prior to any experiments of Professor Henry in the science of electro-magnetism; contradicting in this proposition the facts in the history of scientific discovery perfectly established and recognized throughout the scientific world.

"The essence of the charges against Professor Henry is, that he gave false testimony in his deposition in the telegraph cases, and that he has claimed the credit of discoveries in the sciences bearing upon the electro-magnetic telegraph which were made by previous investigators: in other words, that he has falsely claimed what does not belong to him, but *does* belong to others. . . . Your committee do not conceive it to be necessary to follow Mr. Morse through all the details of his elaborate attack. Fortunately, a plain statement of a few leading facts will be sufficient to place the essential points of the case in a clear light." . . .

[After a review of the evidences furnished (unnecessary to be here reproduced), the report proceeds:]

"It thus appears, both from Mr. Morse's own admission down to 1848, and from the testimony of others most familiar with the facts, that Professor Henry discovered the law, or 'principle,' as Mr. Morse designates it, which was necessary to make the practical working of the electro-magnetic telegraph at considerable distances possible; that Mr. Morse was first informed of this discovery by Dr. Gale; that he availed himself of it at once, and that it never occurred to Mr. Morse to deny this fact until after 1848. He had steadily and fully acknowledged the merits and genius of Mr. Henry, as the discoverer of facts and laws in science of the highest importance in the success of his long-cherished invention of a magnetic telegraph. Mr. Henry was the discoverer of a principle, Mr. Morse was the inventor of a machine, the object of which was to record characters at a distance, to convey intelligence; in other words to carry into execution the idea of an electric telegraph. But there were obstacles in the way which he could not overcome until he learned the discoveries of Professor Henry, and applied them to his machine. These facts are undeniable. They constitute a part of the history of science and invention. They were true in 1848, they were equally true in 1855, when Professor Morse's article was published. . . .

"What changed Mr. Morse's opinion of Professor Henry, not only as a scientific investigator, but as a man of integrity, after the admissions of his indebtedness to his researches, and the oft-repeated expressions of warm personal regard? It appears that Mr. Morse was involved in a number of lawsuits, growing out of contested claims to the right of using electricity for telegraphic purposes. The circumstances under which Professor Henry, as a well-known investigator in this department of physics, was summoned by one of the parties to testify have already been stated. The testi-

mony of Mr. Henry, while supporting the claims of Mr. Morse as the inventor of an admirable invention, denied to him the additional merit of being a discoverer of new facts or laws of nature, and to this extent perhaps was considered unfavorable to some part of the claim of Mr. Morse to an *exclusive* right to employ the electro magnet for telegraphic purposes. Professor Henry's deposition consists of a series of answers to verbal, as well as written, interrogatories propounded to him, which were not limited to his published writings, or the subject of electricity, but extended to investigations and discoveries in general having a bearing upon the electric telegraph. He gave his testimony at a distance from his notes and manuscripts, and it would not have been surprising if inaccuracies had occurred in some parts of his statement; but all the material points in it are sustained by independent testimony, and that portion which relates directly to Mr. Morse agrees entirely with the statement of his own assistant, Dr. Gale. Had his deposition been objectionable, it ought to have been impeached before the court; but this was not attempted; and the following tribute to Professor Henry by the judge, in delivering the opinion of the Supreme Court of the United States, indicates the impression made upon the court itself by all the testimony in the case: 'It is due to him to say that no one has contributed more to enlarge the knowledge of electro-magnetism, and to lay the foundations of the great inventions of which we are speaking, than the Professor himself.'"

The committee, in summing up the various testimonies, justly declare of Professor Henry, that "he has freely communicated information to those who have sought it from him, among whom has been Mr. Morse himself, as appears by his own acknowledgments. But he has never applied his scientific discoveries to practical ends for his own pecuniary benefit. It was natural therefore that he should feel a repugnance to taking any part in the litigation between rival inventors, and it was inevitable that when forced to give his testimony, he should distinctly point out what was so clear in his own mind and is so fundamental a fact in the history of human progress, the distinctive functions of the discoverer, and the inventor who applies discoveries to practical purposes in the business of life.

"Mr. Henry has always done full justice to the invention of Mr. Morse. While he could not sanction the claim of Mr. Morse to the *exclusive* use of the electro-magnet, he has given him full credit for the mechanical contrivances adapted to the application of his invention. . . .

"Your committee come unhesitatingly to the conclusion that Mr. Morse has failed to substantiate any one of the charges he has made against Professor Henry, although the burden of proof lay upon him; and that all the evidence, including the unbiased admissions of Mr. Morse himself, is on the other side. Mr. Morse's charges not only remain unproved, but they are positively disproved.

"Your committee recommend the adoption of the following resolutions:

"*Resolved*, That Professor Morse has not succeeded in refuting the statements of Professor Henry in the deposition given by the latter in 1849, that he has not proved any one of the accusations against Professor Henry, and that he has not disproved any one of his own admissions in regard to Professor Henry's discoveries in electro-magnetism, and their importance to his own invention of the electro-magnetic telegraph.

"*Resolved*, That there is nothing in Professor Morse's article that diminishes in the least, the confidence of this Board in the integrity of Professor Henry, or in the value of those great discoveries which have placed his name among those of the most distinguished cultivators of science, and have done so much to exalt the scientific reputation of the country.

"*Resolved*, That this report, with the resolutions, be recorded in the Proceedings of the Board of Regents of the Institution."

The report was accepted, and the resolutions were unanimously adopted by the Board of Regents.*

* *Smithsonian Report* for 1857, pp. 88–98.

NOTE I. (From p. 62.)

OVERSTATEMENT OF MORSE'S INVENTION.

It was perhaps to have been expected that the owners of the Morse patents, knowing the influence which the unbiased opinions of Henry (subpœnaed as an expert) undoubtedly exercised upon the minds and decisions of the justices before whom the telegraph suits were brought for trial, should regard with much stronger feeling what seemed to them *adverse* in his testimony, than what was really favorable to their interests. But that the sweeping assumptions advanced by the claimants were unwarrantable, has been distinctly affirmed by the highest judicial authority.

Justice Woodbury, presiding at the United States Circuit Court (Massachusetts), in his decision in 1850, in the case of "Smith *vs.* Downing and others," remarked of the successive reissues of the original Morse patent, with expanding claims: "In his last renewal of 1848 there are introduced for the first time some changes of language, and some tendencies in a part of them (as well as in some of the arguments) to make the claim broader, and as in the letter just quoted, to cover all applications of electro-magnetism, if not of electricity, to convey intelligence, or to telegraph to a distance. . . . As this broader claim goes far beyond what we have already seen was that made in the caveat and in the first specification and in the original patent, as well as in all the subsequent renewals; as it conflicts with much of the language of this very last renewal, looking only to a new method and a mere improvement on what existed before; and as he seems to disavow it in his own evidence; and as on everything in the case, it is at least questionable whether he could have intended to patent anything except an improvement on what before existed, I do not think it just to place a broader construction on his language than the whole subject-matter and description and nature of the case seem to indicate as designed. . . . And I the more readily adopt this course for his own protection, as such broader view might subject his patent to be considered void, both for claiming too much, and for claiming also the invention of a mere principle. It would be claiming too much, as it would cover the application in every way—of electro-magnetism to telegraphs: when this as will be seen hereafter by the history of this subject, and as is sworn to by a large number of highly intelligent experts, had been known publicly and for years before Morse's first attention to the subject in 1832. Indeed he himself virtually admits the truth of this in his testimony. Others no less than the persons cited, as well as the history of the progress on this subject, show that several had before Morse not only made this discovery, but applied both electricity and electro-magnetism to the purpose of telegraphing. But if by his alphabet and record, he has been successful in making an improvement in the use of electricity for that purpose, and wished to secure the new method of doing it, he was at liberty in point of law to make out a patent for that new mode; but for nothing more. He came into the world too late for truly claiming much as new. A large galaxy of discoverers on this subject had preceded him."

To a similar purport was the language of Chief Justice Taney of the Supreme Court of the United States in his final decision in the case of "O'Reilly and others *vs.* Morse and others;" which however went so far as to condemn as untenable the substance of the eighth claim introduced by Morse's reissued patent of 1848. The Chief Justice said: "It is impossible to misunderstand the extent of this claim. He claims the exclusive right to every improvement, when the motive power is the electric or galvanic current, and the result is the marking or printing intelligible characters signs or letters at a distance. . . . The patent confers on him the exclusive right to use the means he specifies to produce the result or effect he describes,—and nothing more. . . . Indeed, if the eighth claim of the patentee can be maintained, there was no necessity for any specification further than to say that he had discovered that by using the motive power of electro-magnetism he could print intelligible characters at a distance. We presume that it will be admitted on all hands, that no patent could have issued on such a specification."*

**Howard's Reports*, vol. xv, pp. 112–119.

NOTE J. (From p. 62.)

HENRY'S APPRECIATION OF PROFESSOR MORSE.

Although Henry (together with several other eminent physicists and electricians,) was summoned by the contestants of Professor Morse's patent, his testimony tended probably quite as much to sustain what appeared to him the patentee's equitable claims, as to restrain his overshadowing pretensions. That both before and after these legal controversies, Henry cherished only kindly feelings toward Professor Morse, the following correspondence will sufficiently attest.

At the close of October, 1837, Henry had learned from Professor Gale, with a naturally warm interest, of his success in operating the Morse recorder by a proper adjustment of the length of coil on his Henry magnet, and a battery of 87 cells (each having about 14 square inches of zinc surface), through the length of five miles of cotton-wrapped copper wire (one-sixteenth of an inch in diameter), coiled on a large reel.* And on the 13th of November following, he was informed of his further success in interposing a second similar reel of wire (making ten miles) in the circuit, with but little diminution of effect.

In the following year, 1838, Henry, during his elaborate and profound researches on electrical "induction" (since become classical), desired to borrow one of these five-mile reels of wire, for the purpose of pressing his inquiries to their furthest extent. Professor Morse being then absent in Europe, his colleague Professor Gale very cheerfully lent the wire. On returning the borrowed wire in 1839, Henry, in acknowledgment of the courtesy, sent both to Professor Gale and to Professor Morse a copy of his memoir (read before the American Philosophical Society, November 2, 1838), "with the respects of the author."

Professor Morse, on his return, addressed a letter to Henry, dated New York, April 24, 1839, in which he said:

"My Dear Sir: On my return a few days since from Europe, I found directed to me, through your politeness, a copy of your valuable "Contributions," for which I beg you to accept my warmest thanks. . . .

"I was glad to learn, by a letter received in Paris from Dr. Gale, that a spool of five miles of my wire was loaned to you, and I perceive that you have already made some interesting experiments with it. In the absence of Dr. Gale, who has gone South, I feel a great desire to consult some scientific gentleman on points of importance bearing on my telegraph. I should be exceedingly happy to see you, and am tempted to break away from my absorbing engagements here to find you at Princeton. In case I should be able to visit Princeton for a few days, a week or two hence, how should I find you engaged? . . . I have many questions to ask, but should be happy in your reply to this letter of an answer to this general one: Have you met with any facts in your experiments thus far that would lead you to think that my mode of telegraphic communication will prove impracticable? . . . I think that you have pursued an original course of experiment, and discovered facts of more value to me than any that have been published abroad. I will not trouble you at this time with my questions until I know your engagements. Accompanying this is a copy of a report made by the Academy of Industry, of Paris, on my Telegraph, which I beg you to accept.

"Believe me dear sir,

"With the highest respect,

"Your most obedient servant,

"Samuel F. B. Morse."

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* This coil of wire, wound on a small axis of iron, formed a solid cylinder eighteen inches long and thirteen inches in diameter. Professor Gale's preparation for this experiment was noticed in Silliman's *Am. Journal of Science* (October, 1837, vol. xxxiii, p. 187). And Professor Morse, in a letter to Mr. A. Vail, dated October 7, 1837, congratulated himself that "Professor Gale's services will be invaluable to us, and I am glad that he is disposed to enter into the matter with zeal."

To this letter Henry replied as follows:

PRINCETON, May 6, 1839.

DEAR SIR: Your favor of the 24th ultimo came to Princeton during my absence, which will account for the long delay of my answer. I am pleased to learn that you fully sanction the loan which I obtained from Dr. Gale of your wire; and I shall be happy if any of the results are found to have a practical bearing on the electrical telegraph. It will give me much pleasure to see you in Princeton after this week; my engagements will not then interfere with our communications on the subject of electricity. I am acquainted with no fact which would lead me to suppose that the project of the electro-magnetic telegraph is impracticable; on the contrary, I believe that science is now ripe for the application, and that there are no difficulties in the way, but such as ingenuity and enterprise may obviate. But what form of the apparatus, or what application of the power, will prove best, can I believe be only determined by careful experiment. I can say however that so far as I am acquainted with the minutiæ of your plan, I see no practical difficulty in the way of its application for comparatively short distances;* but if the length of the wire between the stations be great, I think that some other modification will be found necessary in order to develop a sufficient power at the farther end of the line.† I shall however be happy to converse freely with you on these points when we meet. In the meantime, I remain,

"With much respect,

"Yours, &c.,

"JOSEPH HENRY."

A short time after this, Professor Morse visited Henry at Princeton: and during this first personal interview in May, 1839, received satisfactory answers to various questions presented. Among them, Henry stated that he had no reason to doubt that magnetism could be induced in soft iron "at the distance of a hundred miles or more by a single impulse or from a single battery:" (a striking expression of faith in his own "intensity" magnet:) also, that with a given battery, circuit, and electro-magnet at a distance, the inclusion of intermediate electro-magnets at way-stations would not sensibly reduce the magnetic power at the several points. On the subject of the differences between "quantity" and "intensity" magnets, Professor Morse was still greatly in the dark, and he asked the question, "Is it quantity or intensity which has most effect in inducing magnetism in soft iron?" Henry fully explained to him that for producing the greatest magnetic effects, a "quantity" magnet and battery, with short and free circuit, were required: but that for a long circuit (required for magnetizing at a distance), an "intensity" magnet and battery were indispensable.‡

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* [It must be borne in mind that this was a year and a half after the writer had been informed by Dr. Gale of his successful experiment through ten miles of wire. By "comparatively *short* distances," therefore, he must evidently have intended distances less than those separating our principal cities.]

† [The peculiar form of expression here used, suggesting the probable occasion for another modification "in order to *develop a sufficient power—at the farther end of the line*," points directly to his own contrivance (exhibited before his classes, four years previously) of a supplemental "quantity" magnet and battery at the distant station. Henry had no doubt of being able to magnetize iron at a distance of several hundred miles, and hence evidently did not contemplate dividing the line into a "relay" of circuits, as devised by Professor Morse. His language that a re-enforcement may be necessary "*if the length of the wire* between the stations be great," plainly shows this. But he anticipated that the attractive power developed would be feeble; while he declared his confidence that there were no *scientific* "difficulties in the way." Surprise has been expressed that Henry did not frankly give Professor Morse the benefit of this solution of the suggested difficulty, if it were then in his mind. But is not the subsequent reticence of Professor Morse, on the expedient of a "relay" (invented by him two years previously, as alleged), much more surprising? Henry referred to the enfeeblement on a long line, as a merely "practical difficulty" easily "obviated by ingenuity."]

‡ Of the communications made on the occasion of this very interesting and important interview, occupying an "afternoon and evening," we have unfortunately only the result furnished by Professor Morse's very meager statement. (Prime's *Life of Morse*, chap. x, p. 422.) That Henry, in explaining the differing functions of the two

During the long and weary interval in which Professor Morse—with hope deferred—was unavailingly prosecuting his memorial to Congress for assistance, Henry wrote to him the following encouraging and friendly letter:

"PRINCETON COLLEGE, February 24, 1842.

"MY DEAR SIR: I am pleased to learn that you have again petitioned Congress in reference to your telegraph, and I most sincerely hope you will succeed in convincing our representatives of the importance of the invention. In this you may perhaps find some difficulty; since in the minds of many, the electro-magnetic telegraph is associated with the various chimerical projects constantly presented to the public, and particularly with the schemes so popular a year or two ago, for the application of electricity as a moving power in the arts. The case is however entirely different in regard to the electro-magnetic telegraph. Science is now fully ripe for this application, and I have not the least doubt, if proper means be afforded, of the perfect success of the invention. The idea of transmitting intelligence to a distance by means of electrical action has been suggested by various persons from the time of Franklin to the present; but until within the last few years, or since the principal discoveries in electro-magnetism, all attempts to reduce it to practice were necessarily unsuccessful. The mere suggestion however of a scheme of this kind, is a matter for which little credit can be claimed, since it is one which would naturally arise in the mind of almost any person familiar with the phenomena of electricity; but the bringing it forward at the proper moment, when the developments of science are able to furnish the means of certain success, and the devising a plan for carrying it into practical operation, are the grounds of a just claim to scientific reputation as well as to public patronage. About the same time with yourself, Professor Wheatstone, of London, and Dr. Steinheil, of Germany, proposed plans of the electro-magnetic telegraph; but these differ as much from yours as the nature of the common principle would well permit: and unless some essential improvements have lately been made in these European plans, I should prefer the one invented by yourself.

"With my best wishes for your success, I remain, with much esteem,

"Yours truly,

"JOSEPH HENRY."

Professor Morse's biographer, in reproducing this letter, makes the comment: "This was the most encouraging communication Professor Morse received during the dark ages between 1839, and 1843." And he again notices it on a subsequent page: "In the summer of 1842, Professor Morse communicated to the Hon. W. W. Boardman, member of the House of Representatives in Congress, the encouraging letter from Professor Henry, of February 24, 1842."* And when on December 30, of 1842, the Hon. Charles G. Ferris, of New York, reported in the House of Representatives the bill authorizing the construction of the telegraph, this justly valued testimonial of Henry, accompanied Professor Morse's memorial. The Hon. Fernando Wood, of New York (a colleague of Mr. Ferris), in reviewing the history of that enactment some thirty years later, (on the occasion of the memorial proceedings at the Capitol in honor of Professor Morse,) did not forget to remark: "With this letter [from Professor Morse] was another to him from Prof. Joseph Henry, now of the Smithsonian Institution, and then of Princeton College, indorsing and sustaining the application. Professor Henry was deemed high authority on all scientific subjects generally, and especially upon this, to which he had devoted much attention, being himself a successful investigator in electro-magnetic science."† The bill of Mr. Ferris passed the House of Representatives,

kinds of magnets, would have unfolded the utility of the "quantity" magnet as a terminal re-enforcement of a long "intensity" line, seems highly probable,—if not almost inevitable. If Professor Morse did not profit by it, or failed rightly to apprehend it, this may be explained by his possible preoccupation with the project of dividing a long line into a succession of "relays."

*Prime's *Life of Morse*, chap. x, pp. 423 and 433.

† *Memorial of F. S. B. Morse*, April 16, 1872, Washington, 1875, p. 79.

February 23, 1843; and the Morse appropriation was secured, by passing the Senate, March 3, 1843.

Very shortly after this successful issue, Prof. James C. Fisher, who in the absence of Dr. Gale had taken his place in assisting Professor Morse, wrote to Henry explaining the method proposed for insulating the wires and laying the line of conductors underground, and asking advice as to the best method of wrapping. To this communication Henry replied by letter dated—

"PRINCETON, April 17, 1843.

"DEAR SIR: A friend of mine in Trenton has a machine for winding wire of which he promised to give a description. I will write to you on the subject and send you a copy of his answer. The greatest practical difficulty you will have to contend with, I should think, will be the insulation of the wires. Twine is a partial conductor, and by making the surface sufficiently extended, lateral transmission will take place to some extent. The loss however on this account can only be determined by direct experiment with extended wire. It will probably increase with an increasing ratio; first on account of the greater surface of contact, and secondly because electricity of greater tension will be required to send the current through the longer wire. In order to diminish the number of points of contact, it might perhaps be well to wrap around each wire—besides its continuous covering, an extra strand of coarse twine, with the several turns at a distance from each other. . . ."

When Professor Morse, in August, 1843, received 160 miles of covered copper wire, designed to form two independent circuits, each of a double line of 40 miles in extent, to reach from Washington to Baltimore (one pair for the outgoing circuit and the other for the return circuit), he invited Henry and others to be present at a preliminary experiment in New York City, on the 8th of August, to test the capacity of electrical transmission. This very interesting trial with so unusual a length of conductor would for the first time decide the correctness of Henry's opinion that magnetization could be effected "at the distance of a hundred miles or more by a single impulse." This critical test—never before attempted, Henry was unfortunately prevented from witnessing, by reason of his professional duties. The experiment was eminently successful with a battery of 100 Grove elements; and the magnet was operative with even half that number. The following letter to Professor Morse expressed Henry's regrets at being compelled to miss such an opportunity:

"PRINCETON, August 22, 1843.

"MY DEAR SIR: I hope you will pardon me for not before acknowledging the receipt of your kind letters of invitation to attend your galvanic exhibition. My time has been so much occupied during the last three weeks with an extra course of lectures and our examination, and so little at my own disposal, that I was unable to say whether I could be in the city on the day you mentioned or not. I did hope however to get away, but the examination prevented. Dr. Torrey was also engaged, and could not leave. I do not know however that I could have done much in the way of original experiments in the course of a single day. I am not quick in the process of inventing experiments unless my mind is thoroughly aroused to the subject by several days' exclusive attention to the work, and then I am obliged to pause between each effort.* I have not been able since I last saw you to devise a satisfactory process for determining the velocity of *galvanic* electricity; and on reflection I did not think it worth the expense which would be incurred, to have a machine constructed for the mere repetition of the experiments of Wheatstone.

"I think it probable that I shall visit the city next week, as I shall be unemployed from this time until a week from next Monday. If there is any prospect of your

*[An indication of the logical care bestowed by Henry on his experimental work, and the key to his successes. He had little confidence in the profit of empirical or "hap-hazard" trials.]

repeating any of your experiments previous to that time. I will be with you on any day you may appoint.

"With much respect and esteem,
"Yours truly,
"JOSEPH HENRY."

The answer to this, or whether any farther preliminary experiments were jointly performed on the 160 miles of wire, does not appear. As the line of wires between Washington and Baltimore was being laid, Henry, anxious to emphasize the importance of keeping the separate wires at some distance apart throughout their circuit, addressed to Professor Morse the following friendly letter on the subject:

"PRINCETON, January 24, 1844.

"MY DEAR SIR: I am anxious to hear from you in reference to the telegraph, and I have intended to write to you on the subject for a month past, but extra college duties have occupied all my thoughts and all my time since the beginning of the present term. During the last vacation I occupied myself as usual with my investigations in electricity, and among other results, I arrived at one which I think may have an important bearing on the success of the telegraph. It is this: while a current of electricity is passing through a wire, one part of the conductor is constantly *plus* to any other part which succeeds it, the difference in the degree of the electrical state constantly increasing as the distance of the two points is greater. The maximum difference is therefore at the two ends; and when the two extremities of long wires are brought into near approximation, there is a great tendency in the elecricity to cut across from the one to the other. This tendency is not due as has been supposed, merely to the great resistance of the long wire and the cross-cut offering a less resisting channel, but to the fact of the one part being positive and the other negative, and the consequent great attraction of the electricity in the one part for the unsaturated matter in the other. . . . On reading your letter on the subject of the telegraph in the newspapers, I was struck with the idea that you had probably met with the very difficulty my researches have led me to anticipate. If this is the case, and your insulation is not found sufficient, you have no cause to blame yourself, since the previous state of knowledge on the subject of electricity could not lead you to suspect such a condition of things.

"With much respect,
Yours truly,
"JOSEPH HENRY."

The danger apprehended by Henry was realized: and of the nine miles of quadruple conductors laid in the ground, Professor Gale had already discovered that the galvanic current could not be carried through a single mile; a result partly due to the injury done to the insulation of the wires at some points, in the process of enveloping them in a tube, and partly to the energetic induction from the "extra current" first discovered by Henry. In a couple of weeks, Professor Morse wrote to Henry as follows:

"BALTIMORE, February 7, 1844.

"MY DEAR SIR: You must think it strange that I have not answered your letter of the 24th ultimo before this: but I have this moment received it in passing through this place on my way to New York, which I trust will be a sufficient apology for my apparent neglect. I have read your letter with much interest, and it has determined me to make you a visit on my return from New York, which will be the beginning of the week, perhaps on Tuesday morning, the 13th instant. . . . I found the difficulty which you apprehend in the insulation of my wires; but this I will explain when I have the pleasure of seeing you.

"In the mean time, believe me, with sincere respect,
"Your most obedient servant,
"SAMUEL F. B. MORSE."

At his next interview with Henry on the 13th of February, 1844, (on his way *from* New York,) he was advised to suspend his wires through the air on poles, at a sufficient elevation to avoid injury from the recklessness of mischievous boys: as Henry feared that the risk of "cross-cut" on long lines, even with good insulation, was scarcely avoidable.* Henry also informed him that this plan had been successfully adopted by Gauss and Weber ten years previously.

Professor Morse, who had thought of this method before, but with much distrust, at once determined to carry it out, and early in the following month, March, made preparations for its execution. Two methods of suspension were suggested, the first plan (that of Mr. Vail), the gathering of the four wrapped or insulated wires together at their supports, requiring but a single insulator on each pole, to which Professor Morse was himself inclined as involving least cost; the second plan (that of Mr. Ezra Cornell), the scattering of the wires, and the supporting of them apart on independent insulators. The following is Professor Morse's account to Mr. Cornell of a second interview and consultation with Henry on this subject, on the 1st of March, 1844, (on his way *back to* New York,) which he inadvertently confounds with his preceding interview two or three weeks earlier:

"On my way to New York, where I went to order the fixtures, I stopped at Princeton, and called on my old friend Professor Henry, who inquired how I was getting along with my telegraph.† I explained to him the failure of the insulation in the pipes, and stated that I had decided to place the wires on poles in the air. He then inquired how I proposed to insulate the wires where they were attached to the poles. I showed him the model I had of Mr. Vail's plan; and he said: 'It will not do; you will meet the same difficulty you had in the pipes.' I then explained to him your plan, which he said would answer."‡ And this is the method since universally adopted in this country. On the 24th of May following, the first message was sent over the completed telegraph line by Professor Morse from Washington to Baltimore, and immediately repeated by Mr. Vail from Baltimore back to Washington.

The success of this new enterprise (foreseen, encouraged, and promoted, by Henry) having been assured, various competitors sprang up as usual, (with similar and with dissimilar systems,) to share in its benefits and profits; and in a few years numerous litigations arose in resistance of real or supposed infringements. Notwithstanding the zeal and bitterness infused into these controversies by interested partisans, Henry never lost his interest in the success of Professor Morse's plan of telegraphing; but while desirous that meritorious rival schemes (such as that of the printing telegraph, —first invented by Alfred Vail, in September, 1837, and developed by Royal E. House in 1846, to a practical operation) should have a fair trial, he steadily refused to be made a party to any such discussions; until at last he was summoned by *subpœna* to attend a trial at Boston, to testify to the pre-existing state of the art.§ In occupying

* "Mr. Morse visited me at Princeton to consult me on the arrangement of his conductors. During this visit we conversed freely on the subject of insulation and conduction of wires. I urged him to put his wires on poles." (*Smithsonian Report* for 1857, pp. 112, 113.

† [Such an inquiry would appear superfluous in view of Professor Morse's recent letter dated February 7. The whole coloring of the interview is inaccurate.]

‡ Prime's *Life of Morse*, chap. xi. pp. 479, 480. A treatise on the "Telegraph," just published, gives the following account of the plan adopted: "An arm thirty inches long, with a pin at each end, bearing a glass bureau-knob,—an insulation proposed by Mr. Cornell and approved by Professor Henry, was secured to the upper end of each pole. Around the bureau-knobs the conducting wires were wrapped." (*The Telegraph in America.* By James D. Reid. 8vo. New York, 1879, chap. xi, p. 116.)

§ "A series of controversies and law-suits having arisen between rival claimants for telegraphic patents, I was repeatedly appealed to to act as expert and witness in such cases. This I uniformly declined to do, not wishing to be in any manner involved in these litigations, but was finally compelled under legal process to return to Boston from Maine, (whither I had gone on a visit,) and to give evidence on the subject." (*Smithsonian Report* for 1857, p. 87.)

a position so distasteful to his sensitive and generous nature, it may well be supposed that however reserved and cautious his attitude, and whatever his preferences, the answers (necessarily conscientious) drawn from him by skillful attorneys defending the alleged infringements, and the coloring given to such answers in their elaborate arguments, would be little calculated to please the plaintiffs,—naturally intent on the broadest scope and comprehension of their claims. And from this time, Professor Morse, under the misjudging influence of interested supporters, seemed to forget that Henry had been among the most serviceable and unselfish of his many friends.

In 1854 Professor Morse's patent (of fourteen years from 1840) was about expiring, and an application for its extension for seven years longer, according to the provisions of the law, was pending before the Hon. Charles Mason,—one of the most able, conscientious, and indefatigable of Patent Office Commissioners. Inclined from the testimony he had examined, to believe that the merits of Professor Morse's invention had been greatly overestimated, and that his patent from the breadth of interpretation it had received, was acting to some extent as an obstruction to further progress in the art, he consulted with his friend, Professor Henry, as to the independent value of the Morse system, in view of the antecedent state of the art. Henry, with no other sentiment than that of impartial arbitrator, represented that Professor Morse, without the advantage of scientific culture, had the great merit of having combined and of having energetically developed and established a system of electro-magnetic telegraphy, in its method of signaling and of recording, the most efficient of contemporary methods. He referred to the needle-telegraph of his personal friend, Professor Wheatstone (whom he regarded as one of the most intelligent and ingenious of modern physicists), as being in his judgment inferior practically to the Morse telegraph; and he urged that care should be taken not to let the extravagant pretensions of Professor Morse's would-be friends lead to the opposite error of underrating an invention which was certainly of far greater value to the community, than any remuneration which had yet been reaped by its author from the short-lived monopoly.

The application of the patentee was granted by the Commissioner; and the patent was legally extended for seven years from the 19th of June, 1854. Professor Morse, in ignorance of this service, had at the time unfortunately written (or at least given his signature to) the ungracious and ungrateful assault on Henry, as a pretender in science, and a detractor of merit, when rising fame excited his envy. And early the following year, to the injury of himself alone, had the stricture published in a pamphlet, and widely distributed.

As a sufficient corrective of the strange misconception of his disposition and motives, Henry inquired of Judge Mason, if he recalled their interview on the question of extending the Morse patent; and the Commissioner of Patents responded in the following letter:

"UNITED STATES PATENT OFFICE, March 31, 1856.

"SIR: Agreeably to your request, I now make the following statement: Some two years since, when an application was made for an extension of Professor Morse's patent, I was for some time in doubt as to the propriety of making that extension. Under these circumstances I consulted with several persons, and among others with yourself, with a view particularly to ascertain the amount of invention fairly due to Professor Morse. The result of my inquiries was such as to induce me to grant the extension. I will further say that this was in accordance with your express recommendation, and that I was probably more influenced by this recommendation, and the information I obtained from you, than by any other circumstance, in coming to that conclusion.

"I am, sir,

"Yours very respectfully,

"CHARLES MASON."

"Prof. J. HENRY."

NOTE K. (From p. 65.)

THE DATE OF PROFESSOR MORSE'S "RELAY."

Although the depositions of Professor Morse, and of his principal assistant (given in law suits more than ten years after the event), assign from memory as the date of invention of the "relay" the spring of 1837, all the documentary evidence existing, points rather to the spring of 1838, as the date of its inception. First, we should expect at least a reference to this device in the article prepared for Silliman's Journal of Spetember, 1837, in announcing the intention of experimenting with "a circuit of several miles." Secondly, we should certainly expect to find it spoken of as a saving expedient in the caveat of October 3, 1837, if it were at that time in the author's mind, and he were desirous of protecting it. Thirdly, we should expect to find it unavoidably brought forward (at least as a suggestion) before the committee of the Franklin Institute, February 8, 1838, when the doubt was expressly discussed in the committee's report as to the practicable distance to which the telegraph could be made to signal. This conspiracy of silence, this conspicuous absence (in every published case) of the slightest hint upon the subject, although so directly prompted and invited, is difficult (*ex post facto*) to account for. The earliest documentary reference now extant, to a junction of circuits, occurs in the application for a patent signed by Professor Morse April 7, 1838.

On filing this application in the Patent Office, he had requested that it might be retained in the secret archives, unacted upon, until he should have procured his foreign patents. He left this country for Europe with that object May 16, 1838, and returned to New York April 15, 1839. For a year or more afterward he took no step toward procuring his patent, till he wrote the following letter to the "Hon. H. L. Ellsworth, Commissioner of Patents":

"NEW YORK, May 2, 1840.

"DEAR SIR: I have never received my patent papers from your office. I believe there was something to be done on my part in relation to a drawing for one of the duplicates, which I was prevented from accomplishing by the necessity of preparing suddenly for my visit to Europe with the telegraph. I have nearly completed an improved apparatus for which I intend to take out a patent, adding it to my patent already executed, as an improvement. . . . .

"Your old friend and classmate,

"SAMUEL F. B. MORSE."

To this the Commissioner replied as follows:

"PATENT OFFICE, May 14, 1840.

"SIR: The specifications and drawings of your alleged improvement in the mode of communicating signals by the application of electro-magnetism are herewith returned to you, the explanatory reference in the same not being sufficient to properly illustrate the invention. Some annotations pointing out the parts where these are wanting are marked in pencil in the margin of the description.

"Your favor of the 2d instant has been received: in reply to which the office has to state that the delay attending the granting of your application has not been caused by any want of attention on its part. Some two years since, when your patent was about being issued, a request was made by you that the case might be postponed until you should have received letters patent from the European governments. This request was complied with, and as no communication has been received from you since in relation to the issuing of the patent, the case has been permitted to lie over. The patent will be issued however immediately on the return of the papers.

"Yours respectfully,

"H. L. ELLSWORTH."

The amended specification and a duplicate set of drawings were returned to the Patent Office by Professor Morse, with a letter dated New York, May 18, 1840. It was then discovered that the original oath of invention required by law was defective in

omitting a specific date, the space for the day and the month having been left blank. The applicant having been informed of this by official letter dated May 26, 1840, a new affidavit, properly executed, was sent to the Patent Office May 29, 1840, and the patent was finally issued June 20, 1840.

Whether the true date of the invention of the "relay," by Professor Morse, be 1837, or 1838, is not regarded as a matter of any importance historically, as in either case, he is fully credited with its original conception.

NOTE L. (From p. 68.)

ALPHABETIC BINARY NOTATION.

It seems proper to take some notice of the growth of that beautiful invention, the bi-signal alphabet. Its origin appears to be considerably earlier than that of its congener, the binary arithmetical notation devised by Leibnitz two hundred years ago. An alphabetic code of signals is indeed as old as the time of the Greek historian Polybius (150 years before the Christian era), who describes in the tenth book of his General History a method of signaling to a distance any required dispatch by means of torches,—which he says was invented by Cleoxenus and Democlitus, and perfected by himself. In this scheme the Greek alphabet of 24 letters is distributed into five series or tablets, each comprising five letters: (the last space being vacant.) Then torches (from one to five) exposed on the left side, will indicate the group or tablet; and similar torches raised on the right side, will indicate the place of the letter on the tablet.* This system may obviously be very easily resolved into a bi-signal alphabet. It appears that the emperor Leo VI. (of the eastern division of the empire) about the year A. D. 900, in a chapter of his "Military Tactics," on naval warfare, described a plan somewhat similar to the above.†

An early English example of the bi-signal alphabet is to be found in Francis Bacon's "Advancement of Learning," published in 1605. In this Treatise, discoursing on cryptography, he observes: "We shall here annex a cipher of our own, that we devised at Paris in our youth. . . . The invention is this: let all the letters of the alphabet be resolved into two only, by repetition and transposition; for a transposition of two letters through five places or different arrangements, will denote two-and-thirty differences, and consequently fewer or four-and-twenty,—the number of letters in our alphabet." (It will be remembered that at this date the letters J and U had not been differentiated from I and V.) Bacon then gives an example of "a bi-literal alphabet" consisting of the permutations of "a" and "b" through five places; and he subjoins the comment that "this contrivance shows a method of expressing and signifying one's mind *to any distance*, by objects that are either visible or audible, provided the objects are capable of two differences, as bells, speaking-trumpets, fire-works, cannon, &c."‡

In the "Cyclopædia" of Doctor Abraham Rees, published early in the present century (1802-1819), under the word "cipher" are presented among a variety of interesting alphabetic notations, examples of one formed by the combinations of three characters, and of one formed by two characters; the latter evidently copied from Bacon. The compiler says: "Another mode of corresponding by cipher is striking two, or three, bells of various sizes." After remarking that two symbols require a larger combination for each letter than three, and giving an example of each kind, the writer adds: "The effect will be the same, whether the writer make use of arithmetical characters, letters, dots, lines, mathematical diagrams, or any other sign which admits of two, or of three differences." Employing as an instance the figures 1 and 2, he makes use of five recurrences for each letter, as in the example given by Bacon, and he follows a

* Polybius's *History*; lib. x. cap. 45. Greek and Latin edition of A. F. Didot, Paris. 8vo. 1852. pp. 474, 475.

† "The emperor Leo VI, in his chapter on naval tactics (chap. xix), describes almost exactly Myer's army code, concluding with the remark, 'as the ancients did.'" (*Johnson's Universal Cyclopædia*: edited by Dr. Barnard: art. "Naval Signals," vol. iii. p. 734.)

‡ *On the Dignity and Advancement of Learning*, book vi. chap. i.—Bohn's edition, 1858, pp. 222, 223.

similar order of permutations. The two symbols—the single dot or period (.), and the double dot or colon (:),—are also employed for the same purpose.*

In the following table are displayed several examples of bi-signal alphabets, chronologically arranged.† In the first column, the two symbols "a" and "b," and in the second column the two symbols "1" and "2," may stand for dots, lines, colors, bells, or any other distinctions of sight or sound, as indicated by Bacon and by Rees. In the third column is exhibited the notation of an acoustic alphabet devised by Mr. James Swaim, of Philadelphia, and published in 1829, in a pamphlet entitled "The Mural Diagraph, or the Art of Conversing though a Wall." In this scheme (sometimes designated the *prison* alphabet), the symbol "t" signifies an audible tap or knock, and the "s" an audible scratch.‡ In the next three columns, the two symbols "r" and "l" represent a movement of a galvanometer needle to the *right* and to the *left*. In the last three columns, the symbols "s" and "l" represent a short mark or dot, and a long mark or dash.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	Bacon	Rees.	Swaim.	Schilling.	Gauss & Weber	Steinheil.	Original Morse.	Later Morse.	European Morse.
	1605.	1809.	1829.	- - - -	1833.	1836.	1838.	1844.	1851.
A	aaaaa	11111	t	rl	r	lrl	sss	sl	sl
B	aaaab	11112	tt	rrr	ll	lrrl	ss ss	lsss	lsss
C	aaaba	11121	ttt	rll	rrr	llr	s ss	ss s	lsls
D	aaabb	11122	tttt	rrl	rrl	rl	sss s	lss	lss
E	aabaa	11211	s	r	l	l	s	s	s
F	aabab	11212	ss	rrrr	rlr	lrr	s sss	sls	ssls
G	aabba	11221	sss	llll	lrr	rrl	ss s	lls	lls
H	aabbb	11222	ssss	rlll	lll	rrrr	ssss	ssss	ssss
I	abaaa	12111	ts	rr	rr	r	sl	ss	ss
J	- - - -	12112	t tts	rrll	- - - -	r	ss s	lsls	slll
K	abaab	12122	t t	rrrl	rrr	llr	lsl	lsl	lsl
L	ababa	12211	t tt	lrrr	llr	rll	l′	l′	slss
M	ababb	12212	t ttt	lrl	lrl	rrr	lss	ll	ll
N	abbaa	12221	t tttt	lr	rll	rr	ls	ls	ls
O	abbab	12222	t s	rlr	rl	lll	ss	s s	lll
P	abbba	21111	t ss	llrr	rrrr	rllr	sssss	sssss	slls
Q	abbbb	21112	t sss	lllr	- - - -	- - - -	ssls	ssls	llsl
R	baaaa	21121	t ssss	lrr	rrrl	ll	s s	s ss	sls
S	baaab	21122	t ts	ll	rrlr	llrr	sls	sss	sss
T	baaba	21211	tt tts	l	rlrr	lr	lls	l	l
U	- - - -	21212	tt t	llr	lr	rlr	sll	ssl	ssl
V	baabb	21221	tt tt	lll	rlr	rlr	l	sssl	sssl
W	babaa	12121	tt ttt	rlrl	lrrr	rlrl	ssl	sll	sll
X	babab	22212	tt tttt	lrlr	- - - -	- - - -	ll	slss	lssl
Y	babba	22221	tt s	rllr	- - - -	- - - -	sl	ss ss	lsll
Z	babbb	22122	tt ss	rlrr	rrll	rrll	sls	sss s	llss

* Rees' *Cyclopædia*, vol. viii, art. "Cipher."

† Of two early alphabets for the electric telegraph,—that of Lomond in 1787, and that of Dyar in 1828, no records appear to exist. A plan was suggested by Henry at Albany in 1831 or 1832, for indicating letters on a bell by the number of their position in the alphabet: "a" by 1, "b" by 2, "c" by 3, &c. Thus the words "come back" would be represented by the following taps: 3-15-13-5—2-1-3-11; the word "electro-magnet," by 5-12-5-3-20-18-15—13-1-7-14-5-20. The cipher or zero occurring at the 10th letter "j," and at the 20th letter "t" would be indicated by a rapid rattle of the bell. It does not appear however that this alphabet was actually employed, unless perhaps experimentally.

‡ *The Mural Diagraph*, etc. "Through the wall they are content | To whisper, at the which let no man wonder." Midsummer Night's Dream, v. i. By James Swaim. 16-mo. 24 pages. Philadelphia. Printed by Clark & Raser. 1829. pp. 13, 14. The signs were used numerically; and beyond "26" (the letters of the alphabet) were applied to a numbered vocabulary.

The *first* column in the above tabular view, represents the scheme proposed by Bacon, and designated by him "A Bi-literal Alphabet:" a scheme—as he points out, "practicable in all things that are capable of two differences." The advantage of representing every letter by five tokens, is that it dispenses with the necessity of spacing the letters from each other.

The *second* column represents an alphabet shown and described in Rees' "Cyclopaedia" as already referred to. In this alphabet the first nine letters follow exactly the notation of Bacon. After the interpolated letter J, (which takes the symbol for K,) the remainder of the alphabet from K to V inclusive, follows regularly the notation of Bacon—shifted two letters downward. The only symbols differing from Bacon's, are those for X, Y, and Z.

The *third* column gives the alphabet of Swaim above mentioned. The author has not been successful in arranging for his letters the simplest combinations of taps and scratches which might have been selected: having given to N, R, T, and W, five signals, and to X, six; while four of his signs are sufficient to represent 30 different characters. Moreover by adopting a *numeral* system of designation, he has been driven to the awkward and entirely unnecessary expedient of introducing spaces into letters in seventeen cases, or in two-thirds of the alphabet; that is in all letters following the ninth letter—I.

The *fourth* column gives the alphabet of Schilling, as represented in Vail's "Electro-Magnetic Telegraph:" (page 156.) The date of this is uncertain; involving as it does the question when Schilling first employed a single circuit and a single galvanometer in his telegraphic arrangement. Whether he or Gauss and Weber first devised this very important simplification is equally undetermined; though the presumption is in favor of Schilling having been the first to introduce the bi-signal alphabet into telegraphy. With a judicious distribution of the simplest signs to the most frequent letters, the average number of elementary signals need not exceed two and a half for every letter used, (or just one-half the number required by Bacon's alphabet,) in any lengthy communication. Steinheil, who was very imperfectly acquainted with Schilling's labors, appears to regard his system as imitated from that of Gauss and Weber.*

The *fifth* column gives the alphabet of Gauss and Weber, as represented in Turnbull's "Electro-Magnetic Telegraph." † In this alphabet C and K have the same symbol; as have also F and V.

The *sixth* column gives the alphabet of Steinheil as represented in Dub's *Anwendung des Elektromagnetismus:* Berlin, 1863: (2d ed. 1873, sec. v, page 343:) in Vail's Treatise; (page 182:) and in Turnbull's Treatise: (1853, page 97.) In this alphabet C and K have the same character; I and J have the same: and U and V have the same: the letters Q, X, and Y, being dispensed with. Steinheil remarks of its arrangement, "The alphabet I have chosen represents the letters that occur the oftenest in German, by the simplest signs": a plan also adopted by Schilling and by Gauss.

The *seventh* column gives the original alphabet of Morse, as devised by him (or by his assistant—Mr. Vail) in 1838: and for the first time described in his application for a patent dated April 7, 1838. This is accordingly the alphabet presented in Morse's first patent, dated June 20, 1840. In this, he has given the same symbol to G and J: the same to I and Y: and the same to S and Z. It must be borne in mind that down to the year 1838, Professor Morse had conceived only the naval system of signals by means of numbered words, and the method of recording such numbers by the alternating or continuous zig-zag mark, equivalent to the right and left deflections of Steinheil's register;‡ and that not till some time in January of that year (1838), did he make the great advance of substituting the up and down movement of the armature recorder, for its transverse motion. He then for the first time made his telegraphic communi-

* Sturgeon's *Annals of Electricity*, etc. vol. iii, pp. 448, 450.

† Second edition, 1853, p. 60.

‡ New York *Journal of Commerce*, of September 7, 1837, and of January 29, 1838.

cations by means of an alphabet; and improving on his predecessors, devised this alphabet in its simplest form, of a rectilinear succession of dots and lines.

A few years later, the modification given in the *eighth* column was adopted;* being the code now in use in this country. This second alphabet of Morse retains but seven of the letters in his original alphabet; namely, E, H, K, L, N, P, and Q. The remaining symbols are changed in their application. Both of these alphabets present the anomaly of employing for the letter L the unique symbol, a dash of double length: a symbol whose combinations with dots might have been much more appropriately reserved for designating numerals. And they both also present the very awkward arrangement of introducing in five or six cases, a space in the middle of a letter. This occurred with B, C, D, F, G or J, and R, in the first alphabet, and remains with C, O, R, Y, and Z in the later alphabet. Whence it becomes difficult to distinguish between C and IE, between O and EE, between R and EI, between Y and II, and between Z and SE; and if on the other hand the intra-literal space be made too brief, C or R may easily be mistaken for S, O for I, and Y or Z for H.

The *ninth* and last column gives the alphabet adopted by the Vienna convention in October, 1851, for European languages; as represented in Prescott's larger treatise on *Electricity and the Electric Telegraph*, 1877: (page 480.) This alphabet avoids the obvious blunder in Morse's notation, and presents a homogeneous system. In this code eleven of the Morse letters are changed: C, F, L, and R, having been taken from Gerke's alphabet, O, and P, from Steinheil's, and J, Q, X, Y, and Z, from other sources. Of the *original* "Morse alphabet" only four letters are retained, viz, E, H, K, and N. This European or "international" alphabet is however in a few of its symbols, better adapted to the German than to the English language. Accordingly in the Atlantic cable alphabet, the two letters M (ll), and O (lll), have been transposed; as in English the letter O occurs nearly three times as frequently as the letter M.

We thus perceive by what apparently small steps so simple a contrivance as an alphabetic notation, (scarcely demanding the exercise of invention,) has been successively modified and improved. But although the "Vienna" alphabet is now universally employed elsewhere, American operators have not yet had the intelligent courage to incur the temporary additional labor and inconvenience of change, for the permanent advantage of a more perfect system. †

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* Represented in Vail's Treatise, 1845, p. 27; in Turnbull's Treatise, 1853, p. 73; in G. B. Prescott's *Hist. of Electric Telegraph*, 1860, p. 89; and in F. L. Pope's *Modern Practice of the Electric Telegraph*, 4th ed. 1871, p. 101.

† "It has been proposed to introduce the European alphabet in this country also; but although the advantages of such a reform would doubtless be numerous, yet it may perhaps be better to suffer some inconvenience from an acknowledged imperfection, than to attempt to remedy it by introducing a change that would for a time cause serious annoyance to the thousands of skillful operators now in the service." (Prescott's *Electricity and the Electric Telegraph*, 1877, chap. xxx, p. 431.)